May 1956

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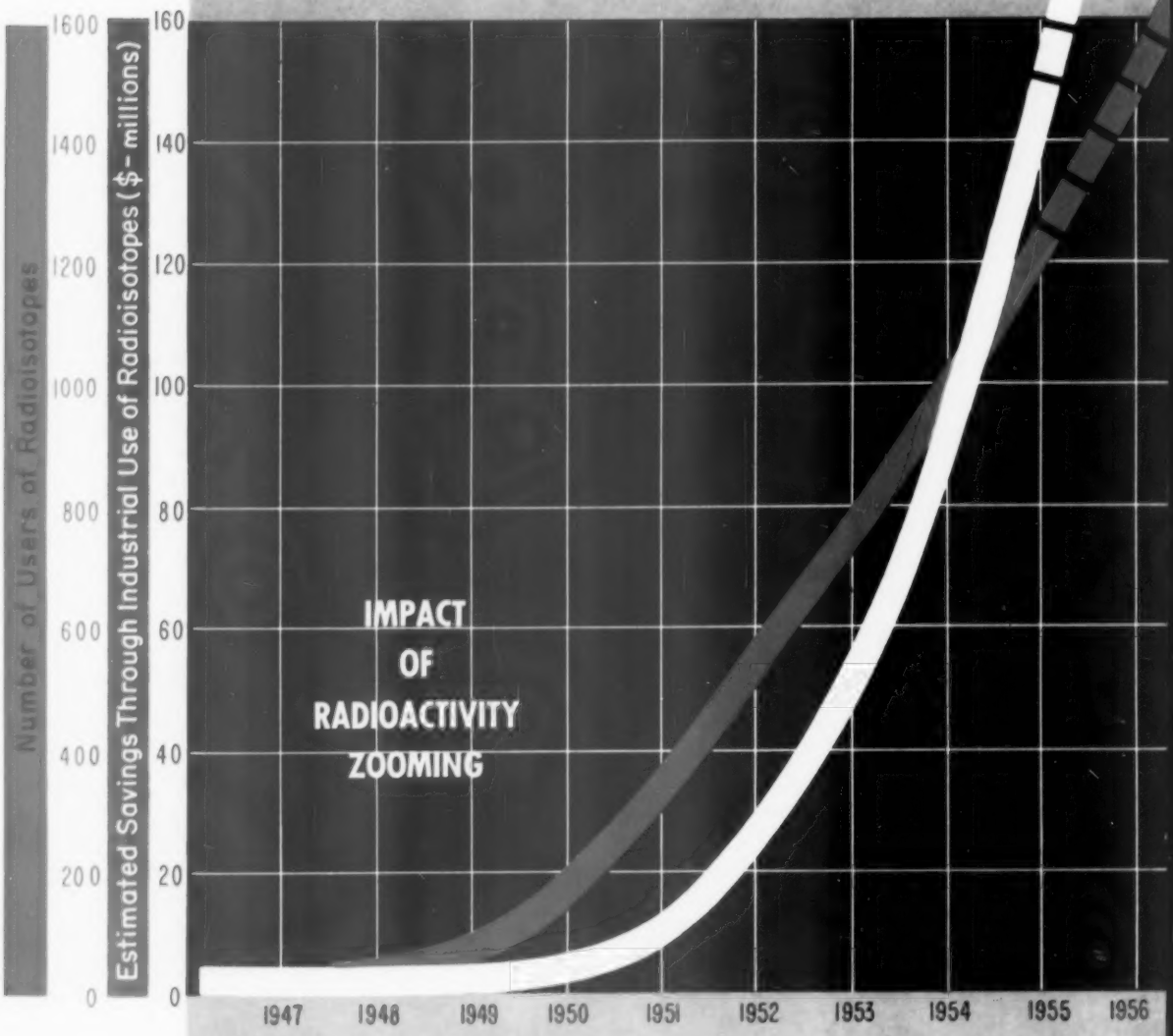

APPLYING RADIATION IN INDUSTRY

A Special Report ... page 41

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NUCLEONICS

MAY • 1956

Vol. 14, No. 5

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About NUCLEONICS

Dear Readers:

This is a personal letter aimed at those of you who are excited and enthusiastic about working in the nuclear field but who don't like the idea of having your view of it confined to one narrow phase. Rather you want an intimate picture of the development of the entire industry. You want an inside picture of what key companies and laboratories in the field are doing. And you want the opportunity of getting to know many of the key people working in the field.

There's one good way to get to do all this. And that's to come to work for NUCLEONICS.

Because so few people have an appreciation of what it's like to work for a technical journal like this, I'm going to take a crack at what may be the impossible—describing the excitement and satisfaction that can come from being an editor.

Our job is to keep up with—and frequently ahead of—the field. Within the limitations of secrecy, we've got to know what's happening, where it's going on, and who's doing it. Not only do we have to know such factual information, but we've also got to have a feel for what it all means—in other words, we've got to

NUCLEONICS

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have our fingers on the pulse of the industry.

To do this, we've got to travel. (Last year, our staff traveled 41,800 miles.) We've got to visit people. (Last year, our staff visited 120 organizations.) We've got to be in touch with people. (Last year, our staff dealt with hundreds of people.) We've got to attend technical and industry meetings. (Last year our staff attended dozens of meetings.) And we've got to be active in professional society affairs. (Last year, our staff was involved in the affairs of at least a half dozen societies.)

The purpose of all this getting around is to get background information for self and staff orientation. It's also to line up contributor articles that will serve our growing international readership. And some of us do our own writing of material for the magazine.

Obviously, for us to be able to do a good job of covering such a broad and complex field as the nuclear energy industry, we've got to have a professional staff with the right background. Each man is a specialist in some phase of the field and has the responsibility for keeping in touch with that phase of the field in addition to being aware of the broader picture.

Thus, on NUCLEONICS at the moment, we have two physicists, one nuclear engineer, one chemist, one electrical engineer and a nontechnical man who handles our news and nontechnical feature coverage.

The technical people were all hired because of their technical backgrounds and not because they had had experience as editors (although we don't turn our nose up at the latter). Then, once they join us (assuming they have the basic ability to communicate information clearly), we train them as editors.

But they never lose contact with their technical interests. In fact, the very nature of our work requires them to develop and expand their technical proficiency.

In addition to maintaining contact with the field, they must pass judgment on manuscripts. Then their most important editorial task is to put the material we publish into a form that will be most digestible by the readers.

Throughout these operations, there is the greatest opportunity to express initiative. We're always looking for new ideas on articles, features, and special reports that we might put together to give the reader something he wants or needs—and for new ideas on how to present this information so the reader can get the ideas fast. It's a tremendous challenge, and it's an exciting one.

Now that my story is told, I can get to the point, which you've probably already guessed—we're looking for a new editor for our staff. We want someone who's preferably had some contact with the reactor field—either in experience or education. Most important, we want someone who wants to share in the excitement of a dynamic publishing venture. If you're the one, write me at 330 West 42 St., New York 36, N. Y., giving me a resume and your salary requirements.

Cordially,
Jerome D. Luntz

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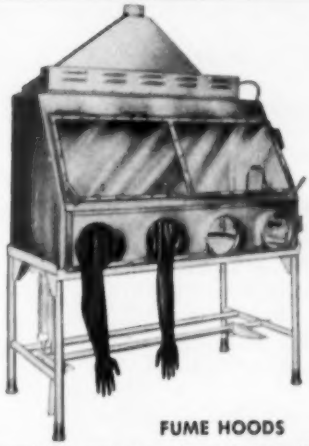
CREVICE-FREE CONSTRUCTION ASSURES EASY CLEANING AND DECONTAMINATION—Blickman equipment is designed for handling radioactive materials, bacteria, viruses and other hazardous substances. Stainless steel, all-welded, seamless round corner construction makes decontamination simple . . . **Send for our booklet**—"A Typical Radio Chemical Laboratory," or for technical bulletins about specific equipment.



FUME HOODS

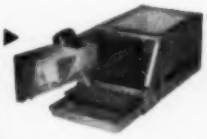
All stainless steel fume hood for handling hazardous substances. Available with or without stand-in units 4, 5, 6 and 8 ft. long. Round corner, crevice-free construction. Bulletins E-1 and E-3.

CONTAINERS

◀ Stainless steel receptacles for radioactive waste. Foot lever rotates segment in cover to eliminate air movement and prevent spread of contamination. Bulletin B-2.

CAGES

Open view of ▶ Blickman stainless steel animal cage. Easy to clean, durable, corrosion resistant. Bulletin C-1.

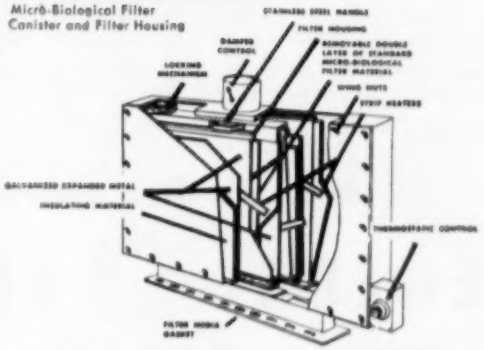


DRY BOXES

◀ Stainless steel low intensity dry box. Rounded corners to facilitate cleaning and decontamination. Available in several sizes. Bulletin A-1.

Micro-Biological FILTER CANISTER

Micro-Biological Filter Canister and Filter Housing



● This micro-biological filter canister is designed to filter out and destroy micro-organisms that may be present in exhaust air from experimental and production work done in the enclosures. It can be adapted to existing equipment or new equipment built for the laboratory, such as hoods, dry boxes and enclosures. These include various types used in biological and pharmaceutical research or production.

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You are welcome to our exhibits at the Federation of American Societies for Experimental Biology Convention, Atlantic City Auditorium, Booth Nos. 67–68, April 16–20, and to the 6th Annual Research Equipment Exhibit and Instrument Symposium, National Institutes of Health, Booth No. 12, Bethesda, Md., May 14–17.

General Electric offers new single-cycle BWR* for atomic power plants

Designed specifically to furnish energy for electric power generation

Forerunner of a whole new family of small power reactors, the General Electric single-cycle boiling water reactor is a new source of energy designed for power plants in a range of 5000 to 20,000 kw. It can be modified for larger ratings.

Boiling in the reactor itself and forced circulation offer these advantages:

(1) Simplified design; no main heat exchanger used. **(2)** High thermal efficiency. **(3)** Automatic control of response to load changes. **(4)** Greater safety since reactor is self-limiting in case of excessive nuclear reactivity.

This reactor uses fuel elements of the long-burn-up type. Spent fuel elements are stored in the service pool adjacent to the reactor until cool enough for further handling.

The reactor and service pool can be equipped for neutron and gamma irradiation for research without interfering with reactor operation.

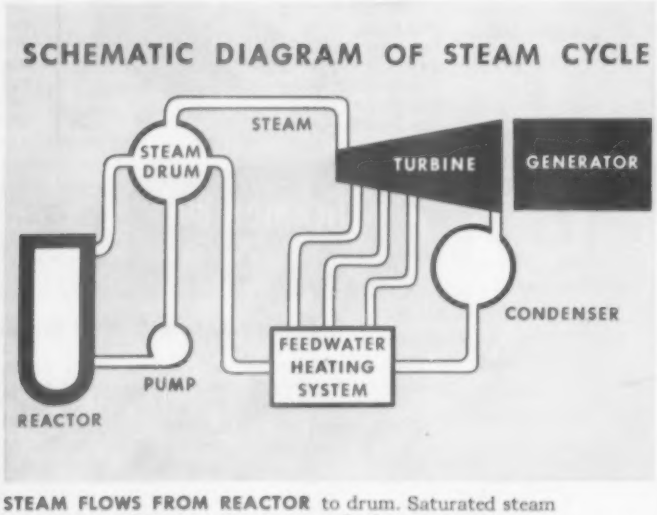
For more information, write for bulletin GER-1220, Sect. 192-7, or contact the Atomic Power Equipment Dept., General Electric Co., Schenectady 5, N. Y.

**Boiling Water Reactor*

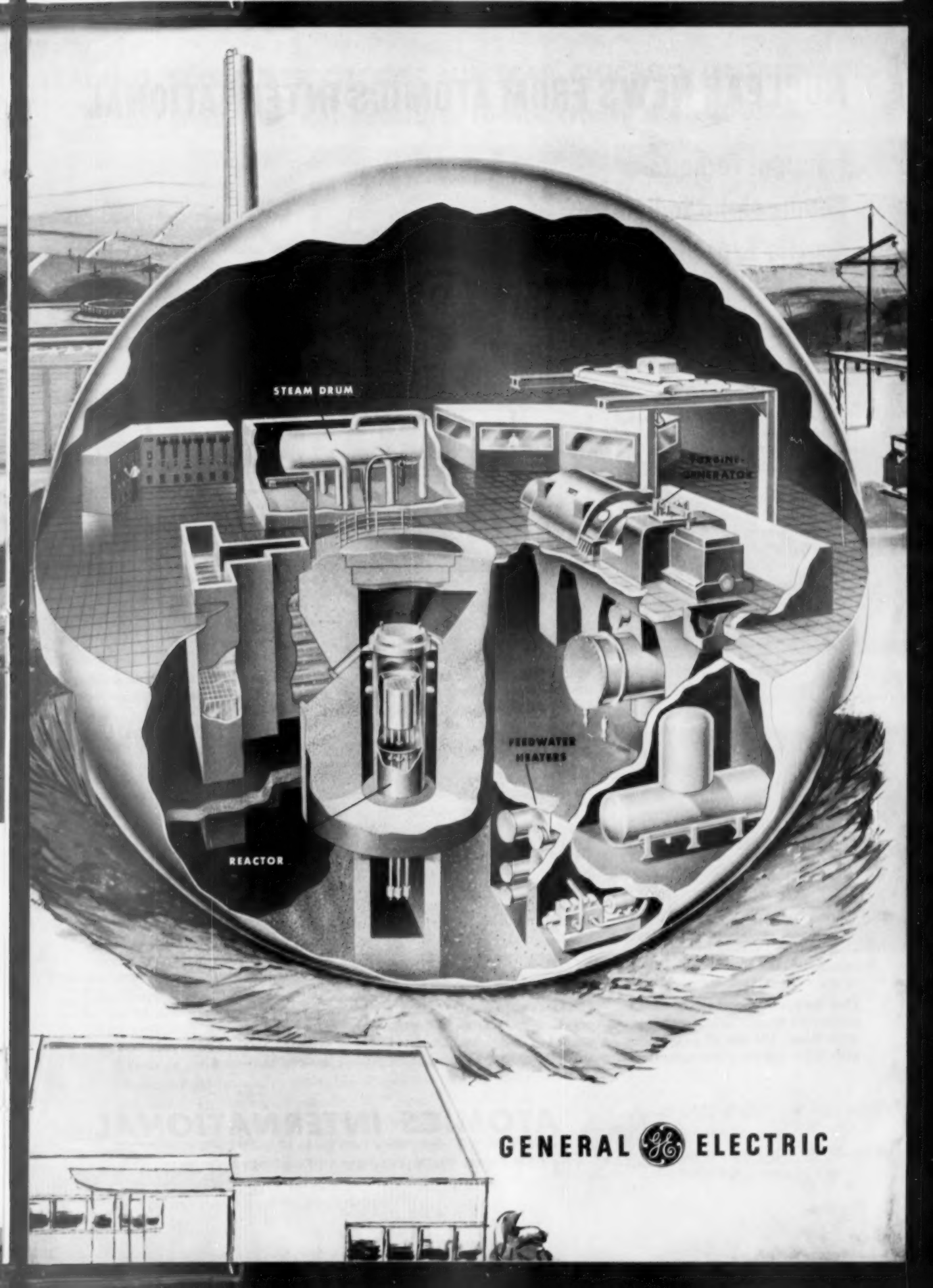
Progress Is Our Most Important Product

GENERAL ELECTRIC

SIMULATED FUEL ELEMENT being installed in a heat transfer loop for tests under reactor thermal conditions. This is one of G.E.'s supporting atomic development programs to advance reactor design.



STEAM FLOWS FROM REACTOR to drum. Saturated steam passes to turbine; water goes to feedwater heaters and returns to steam drum. Forced circulation pump provides automatic control of response to load changes.

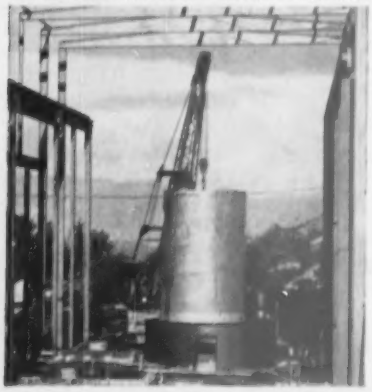


GENERAL ELECTRIC

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

Principal Technical Details of the Sodium Reactor Experiment in California

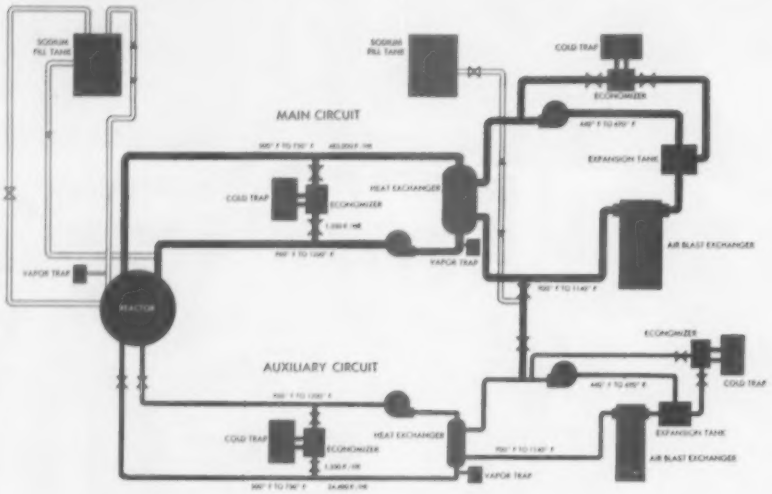
The Sodium Reactor Experiment is an important contribution to the Atomic Energy Commission's program to develop economical power from nuclear energy. Interest in the SRE approach is high. The Atomic Energy Commission has authorized ATOMICS INTERNATIONAL and the Southern California Edison Company to enter into an agreement for Edison to install electrical generating equipment with a capacity of 7,500 kilowatts adjacent to the SRE to convert the reactor's 20,000 kilowatts of heat into electricity which will be fed into the utility's power grid system. ATOMICS INTERNATIONAL and the



SRE reactor core is lowered into place deep in the Santa Susana Mountains

Consumers Public Power District of Nebraska are negotiating for the construction of a 75,000 kilowatt nuclear power plant utilizing a sodium graphite reactor based on SRE experience.

The Sodium-Cooled, graphite-moderated reactor design has many advantages. The use of sodium permits high temperature operation, good steam conditions and high thermal efficiency of power conversion without pressurization of the reactor and coolant circuit. The high thermal conductivity of sodium makes it an excellent heat transfer medium. Sodium boils at 1620°F.—is liquid at 208°F. This permits high coolant temperatures with the system at atmospheric pressure, creating a low-pressure heat extraction system which simplifies reactor construction. Further, the sodium design minimizes chemical reaction between fuel elements, coolants and structural materials—increases safety—allows the use of a variety of steels and alloys in construction.



Sodium Flow Diagram For SRE Cooling System

Nominally Rated Output of SRE with Uranium fuel (enriched with 2.80 atom percent U235) is 20 Thermal Megawatts. The reactor core is made up of fuel rods, moderator cans and control elements interspersed and immersed in sodium coolant. The fuel is composed of 6 inch slugs, 0.750 inches in diameter, formed in 6 foot columns tied in clusters of seven. The graphite moderator elements are canned in Zirconium, fabricated with an axial coolant channel. This prevents absorption of sodium into graphite. Much less costly than beryllium—graphite is also comparatively easy to handle.

Capital and Power Costs in Full Scale Power Stations—At present, with Uranium fuel, capital costs/installed Kw. are expected to total $300. With Thorium, costs may be $265/installed Kw. Power costs (based on 80% load factor and 15% annual fixed charges) may be 11 mills/kwh with Uranium, 9 mills with Thorium. Future costs with Thorium fuel are expected to be $200/Kw capital cost and 6.5 mills/kwh total power costs.

Atomics International is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power. If you are interested in any phase of our activities, ATOMICS INTERNATIONAL is staffed and equipped to help you. Please write: Applications Engineering Service, Department N-N2, ATOMICS INTERNATIONAL, P.O. Box 309, Canoga Park, California. Cable address: ATOMICS.

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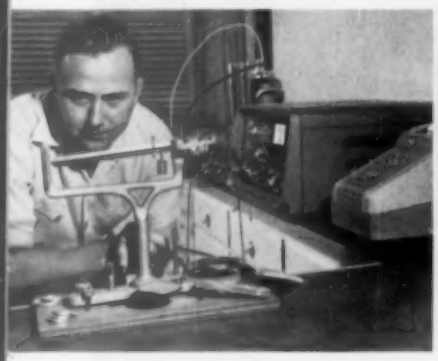
Metabolic Research—Coconut Island, Hawaii.
Marine biologists use Nuclear-Chicago instruments for metabolic research, monitoring fish forced-fed radioactive strontium.



Petroleum Research—Pasadena, California.
Petroleum geologists determine radioactivity of oil well cuttings—use resultant "profile" to expand and develop oil fields.

Industrial Research—New York, N. Y.
Laboratory uses radioactive "dirt" and Nuclear-Chicago instruments to test washing machines, improve soil-removal techniques.

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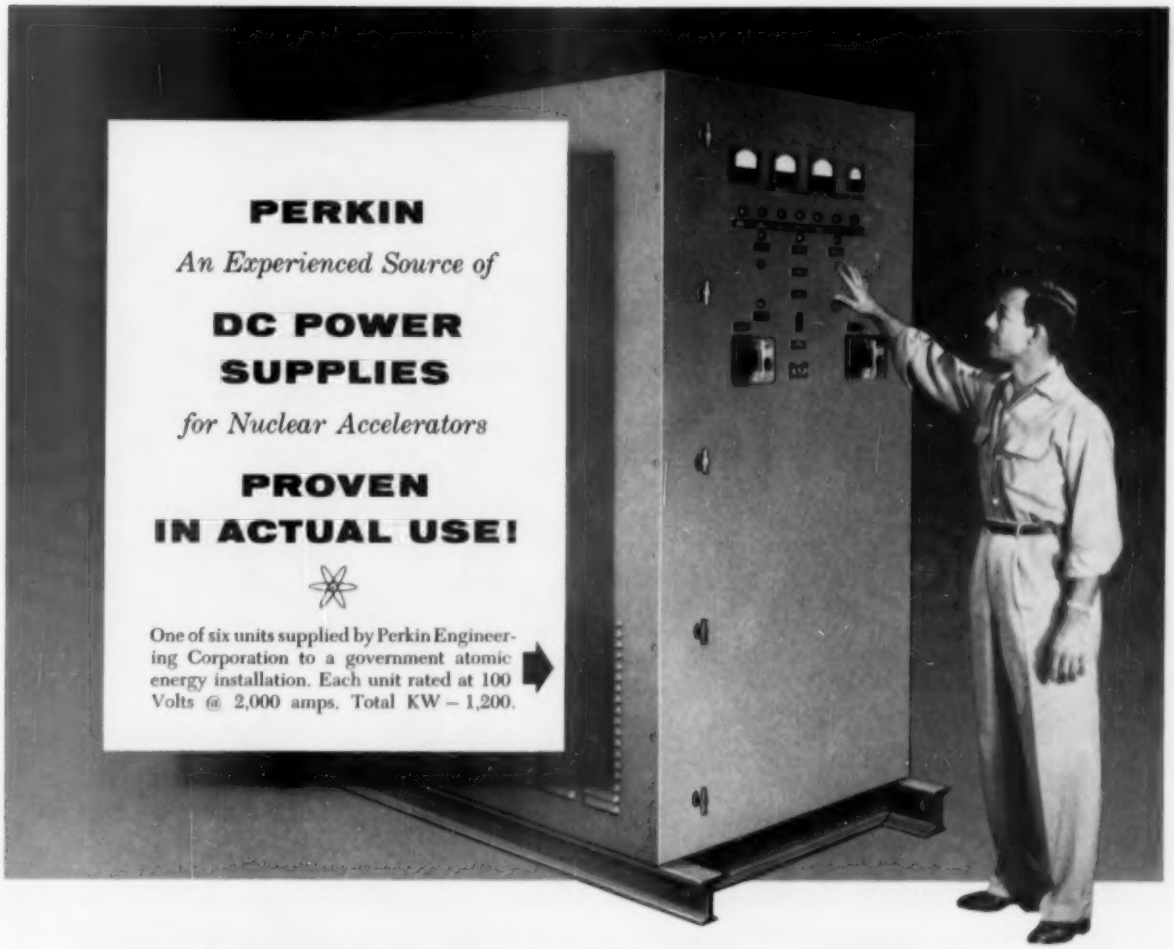
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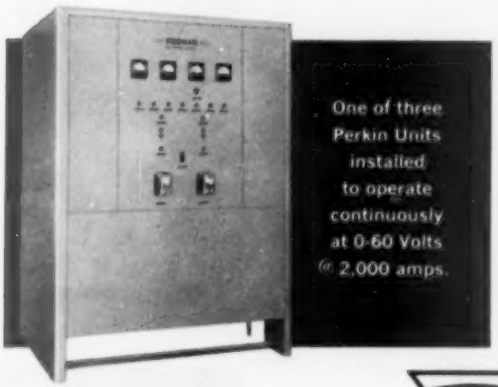
for Nuclear Accelerators
PROVEN IN ACTUAL USE!
One of six units supplied by Perkin Engineering Corporation to a government atomic energy installation. Each unit rated at 100 Volts @ 2,000 amps. Total KW – 1,200.

Perkin Heavy Duty Rectifier Units for Atomic Energy Applications...



Perkin-designed rectifier units supply the DC power for many accelerators now in use at atomic energy facilities throughout the nation. Of primary interest is the fact that many of Perkin's rectifiers are magnetic amplifier controlled—having no tubes to replace—no moving parts—no vibrating contacts. No warm-up time is required. All units are of rugged construction, conservatively designed to provide long, trouble-free service with virtually no maintenance. Units of 1000 KW and above are available in Selenium or Germanium types, recommended according to the application requirements. Perkin also manufactures a standard 50 KW Germanium rectifier unit available for immediate delivery from stock. Write for details.

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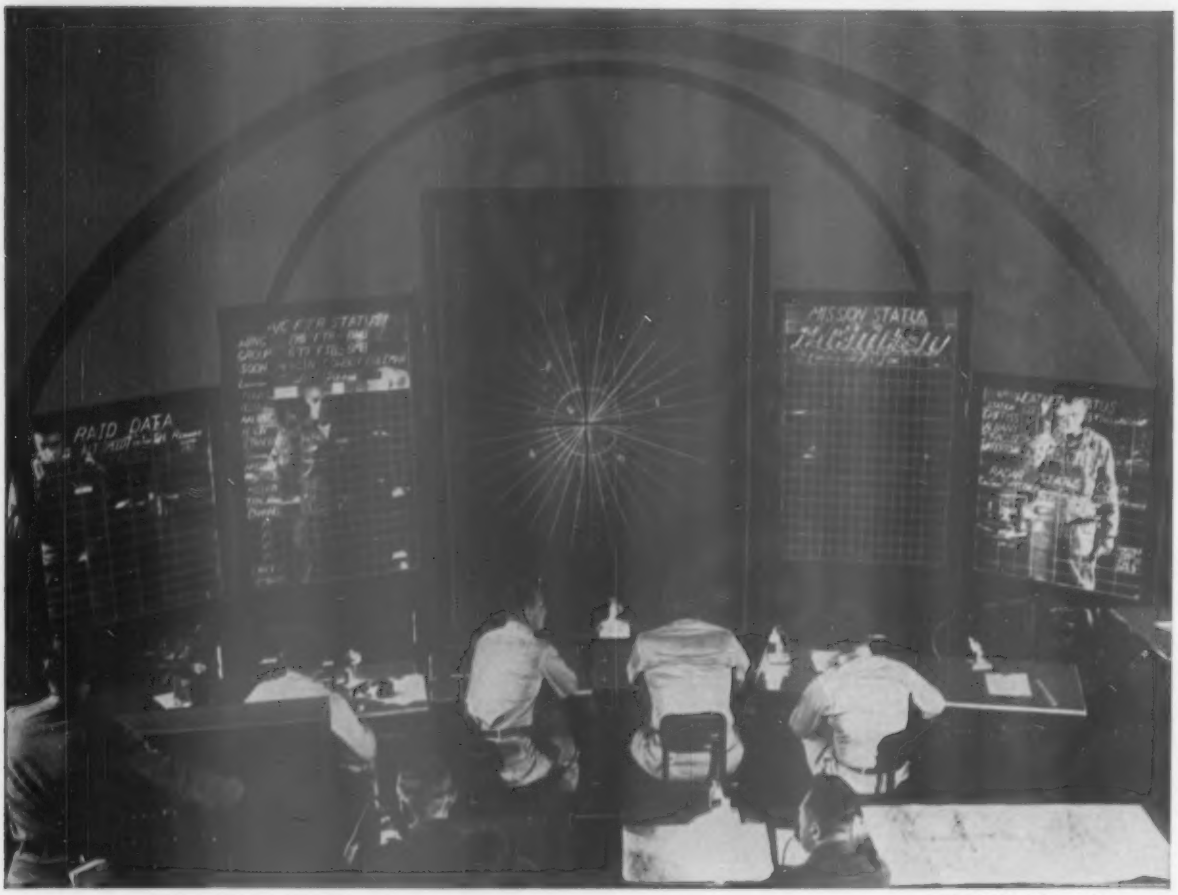

Official U.S. Air Force Photograph

Friend or foe? Tactical defense officers in MINK control center watch movements of aircraft as reported from radar warning sites. This is equipment developed under the direction of Rome Air Development Center.

ROME AIR DEVELOPMENT CENTER PROVIDES AIR DEFENSE EQUIPMENT FOR OUR AIR FORCE

One development agency for the Air Force's ground-based electronic equipment is Rome Air Development Center, located at Griffiss AFB in Rome, N. Y. One of the ten centers of the Air Research and Development Command, RADC is concerned with the air defense of our nation, with providing equipment for tactical supremacy, and with developing ground complexes for various navigation systems to aid all aircraft. In addition, RADC is charged with data handling improvements for the Air Force intelligence mission.

RADC is the responsible center for development, through its various contractors, of such end products as radar sites, including improved tubes, circuits, antennae, and shelters; ground communications equipment and associated support items; IFF (Identification Friend or Foe) environments, and electronic countermeasures.

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This is one of a series of ads on the technical activities of the Department of Defense

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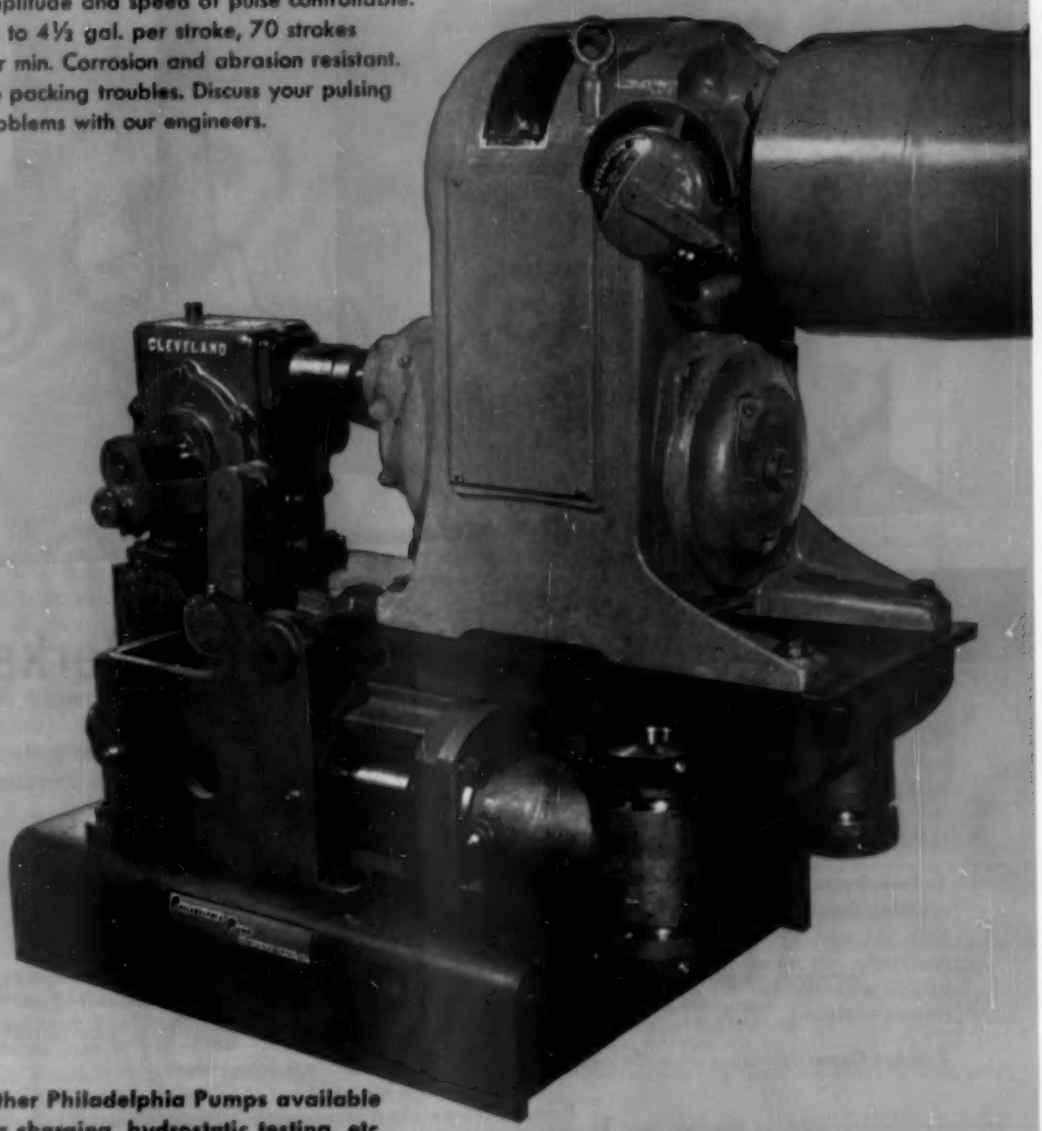

- Other Philadelphia Pumps available for charging, hydrostatic testing, etc.

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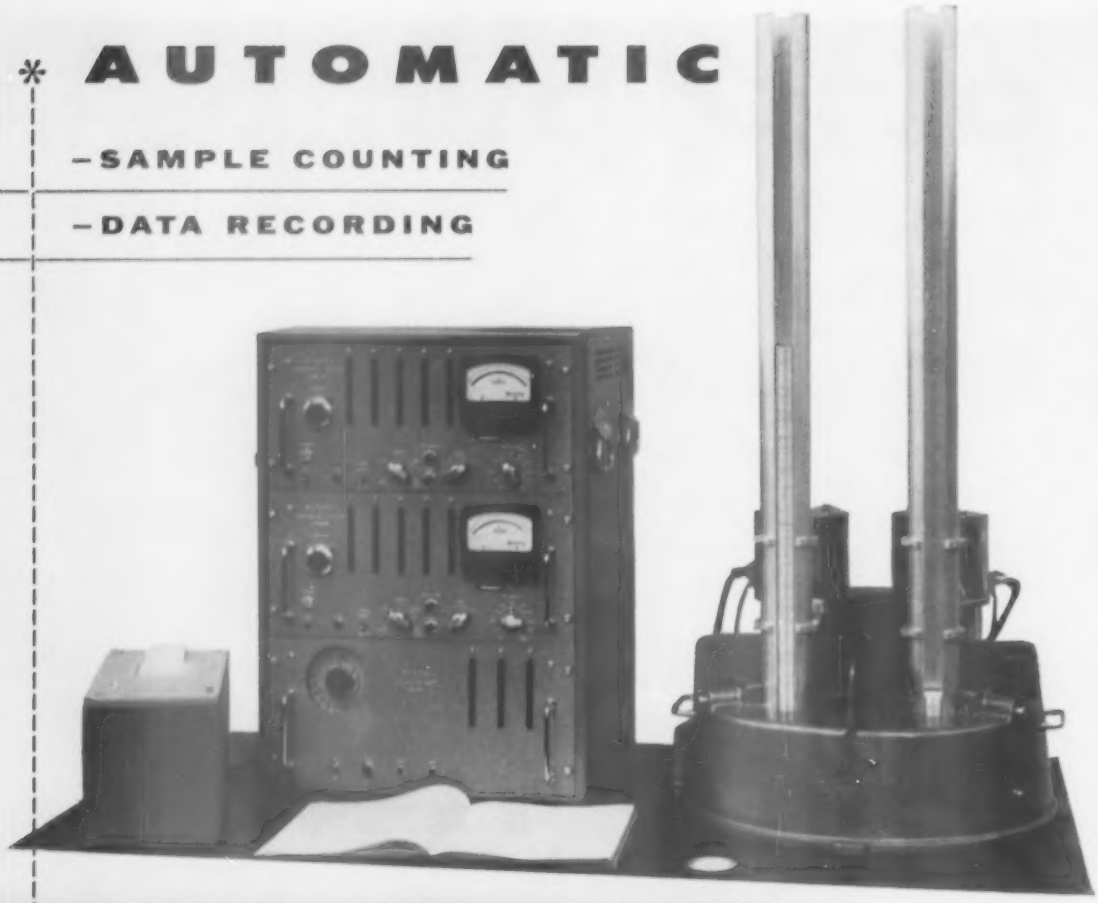
–SAMPLE COUNTING

–DATA RECORDING



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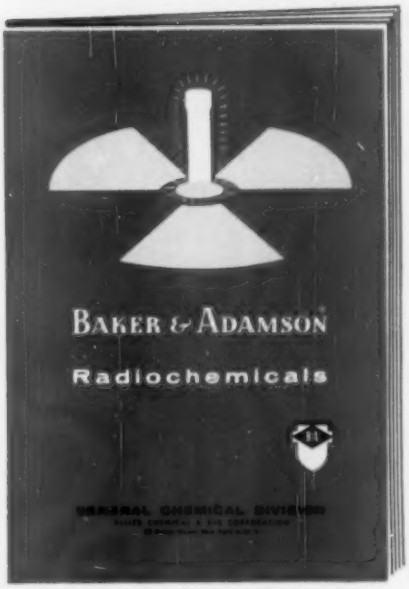
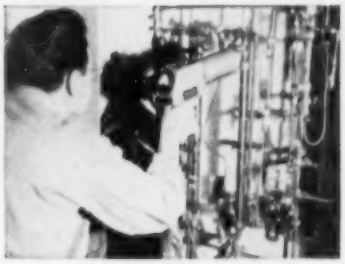


Illustration from catalog showing use of radioactive piston ring to study engine wear (Standard Oil (N.J.) Photo)



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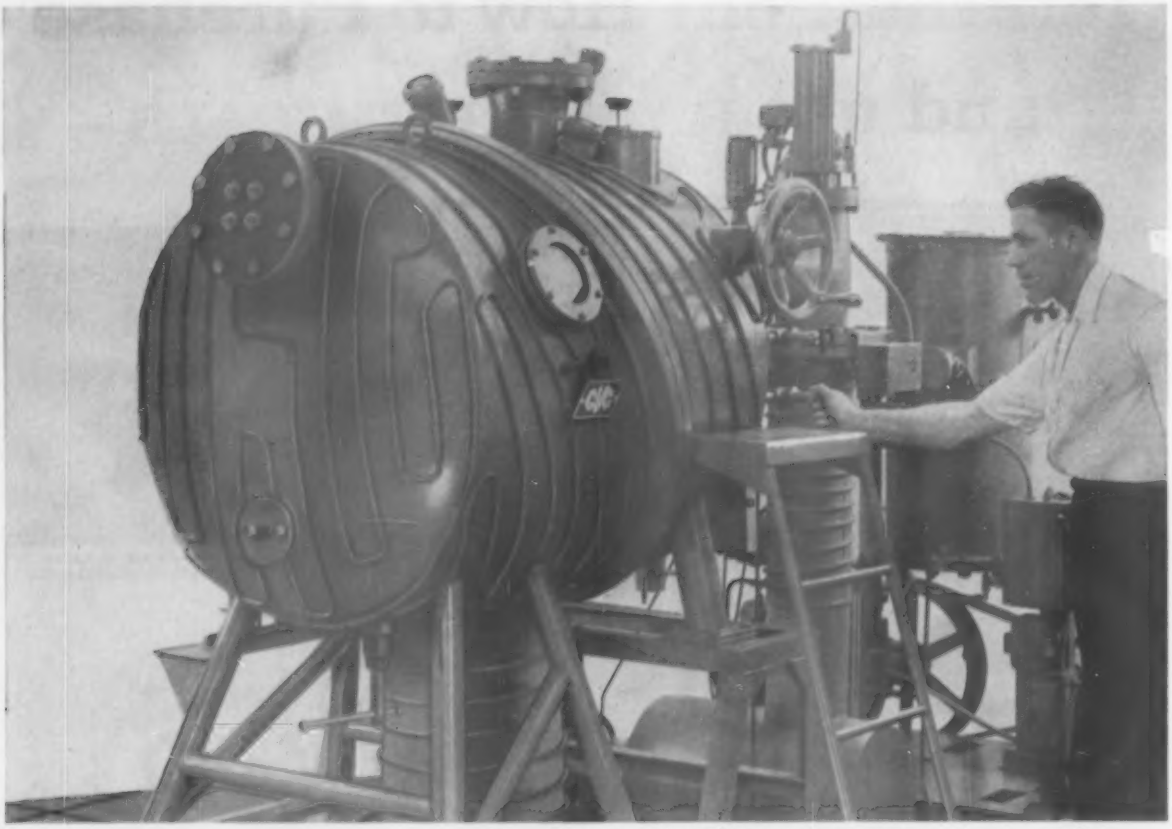

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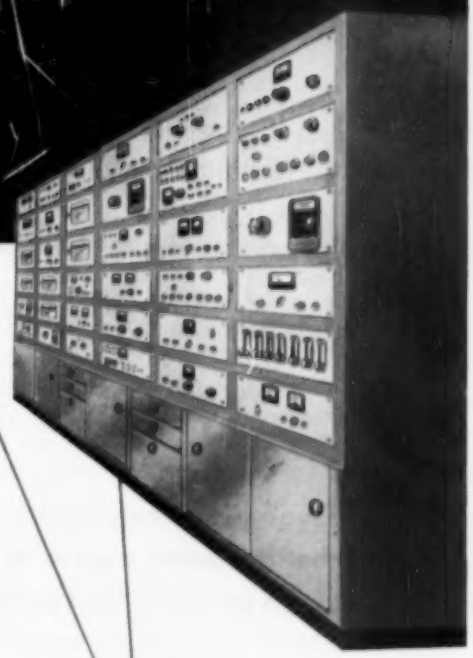

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ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

Power Pacts: 8 Pending?

AEC-State negotiations with foreign countries for power bilaterals have so progressed that AEC hopes to get eight approved this year (all bilaterals must lie 30 days before Congress while it is in session). They would be with Austria, Brazil, France, Italy, India, Norway, Netherlands and Switzerland. They are reported to provide for a supply of 20%-enriched U. S. uranium, and compulsory return to the U. S. for reprocessing. Some of the eight countries are understood to desire no classified U. S. information; yet security arrangements are a major obstacle.

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LMFR Award

Babcock & Wilcox is getting the nod from AEC to build the first prototype liquid-metal-fueled reactor, probably at Brookhaven. 12 firms wanted the job.

•

Salvaging EBR-1

AEC will not know for several months yet the extent of damage to EBR-1, the fuel elements of which melted down when a deliberate power surge, with automatic control circuits disconnected, got out of hand. The incident occurred last Nov. 29; AEC announced it April 5, and then only on pressure from newsmen after the story leaked out (*see p.* 39). Having been able to withdraw only two of the fused fuel elements, AEC is building a coffin around the football-sized core. Into this the remaining elements will be drawn, together with the stainless-steel base-plate to which they are stuck, for study in an Arco hot lab. Maximum power reached during the fateful surge is unknown—it ran off the instrument scale; AEC hopes to reconstruct it from study of the activity and burnup in the damaged fuel elements. To put EBR-1 back into operation would require only new fuel elements; but whether this will be done is a decision that has not yet been taken and on which the hot-lab studies will have no bearing, for AEC was nearing completion of its five-year experimental program with EBR-1.

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World Agency Gets Charter

After one miscarriage last fall, a 12-nation working group gave birth in Washington last month to an acceptable draft statute for the International Atomic Agency (NU, April '56, p. 18). It now remains for an 84-nation conference, due to meet in New York on or about Sept. 24, to approve the draft, which will then be open for signature and ratification; once 18 parliaments have ratified including three of the atomic-Big-Five, IAEA will be in business. Washington hopes this will occur by June 1957.

Last obstacle to agreement on the draft statute was on a formula for the Board of Governors. The complicated compromise adopted has a Board of 23 members in four categories: **1.** the Big Five of U. S., U. K., U. S. S. R., France and Canada; **2.** five regional representatives most advanced in nuclear technology including source material production; the regions are Latin America, Africa and Middle East, South Asia, Southeast Asia and Pacific, and Far East, and the first representatives are expected to be Brazil, Union of South Africa, India, Australia and Japan; **3.** two producers of source materials—Belgium and Czechoslovakia will alternate with Poland and Portugal—plus one supplier of technical assistance, expected to be Sweden; and **4.** ten have-not nations elected at large but with regard to regional representation. Once constituted, this executive will have vastly more power than most: unlike nearly all national and international bodies, the Board of Governors will have final say on operations and policy and the General Conference will have power only to consider, recommend and approve, and to elect the Board within the lines laid down by the Statute. A director-general will head the staff. Location of headquarters has not even been considered yet. IAEA has as its basic objective to "seek to accelerate and enlarge the contribution of atomic energy to the peace, health and prosperity of the world." It will set up a minimum number of depots or storage pools for fissionable material around the world, also laboratories if necessary; and will be

authorized to go into research on its own, even to building its own research reactors, if the members feel such activity worthwhile. In supplying fuel or facilities to member nations, IAEA's basic principle is that its aid must be used for peaceful purposes and strict accountability is required; each aid program will be covered by an agreement between the agency and the recipient country, and it will be up to the Board of Governors to see to it that the agreement provides sufficient authority for IAEA to enforce accountability.

■

Elk River, Hersey OK'd

Two of seven second-round power demonstration reactor proposals (NU, March '55, pp. 19–21) were accepted in principle by AEC: those of Rural Cooperative Power Ass'n. of Elk River, Minn., and Wolverine Electric Cooperative of Hersey, Mich. Both ask AEC to finance and retain title to the reactor portion of the plant. The former proposed a 22-Mw boiling reactor with a heat exchanger and a secondary steam circuit to keep radioactive steam out of the turbine, to be built by AMF Atomics; RCPA will pay $2,450,000 capital costs including site value, and AEC is asked for up to $6,860,000 for development, design and construction, and for waiver of fuel use charges. Wolverine plans a 10-Mw aqueous homogeneous unit with adjoining fuel reprocessing facilities, by Foster Wheeler; it will assume capital costs of $1,088,000 including site, and is asking $3,788,000 for development, design and construction. Details of AEC aid and cost limits remain to be worked out in contract negotiations.

Although AEC said the five other proposals are still being evaluated by its staff, some observers were disappointed that AEC had not made a more forward-looking showing in its first batch of second-round acceptances. AEC said it had determined both Elk River and Hersey plants "would make important contributions to the power reactor art"; yet both basic types have already been demonstrated, in Borax-3 and HRE-1. Some reactor men feel three more audacious proposals could represent greater strides forward: a sodium-cooled, D_2O-moderated project by Chugach Electric Ass'n. of Alaska; and a closed-cycle gas-turbine plant by Holyoke, Mass.; the third, by Piqua, Ohio, is contingent on success of AEC's organic-moderated-reactor experiment to be completed late this year at Arco, Idaho.

●

Fusion Flurries

Soviet scientist Igor V. Kurchatov dropped a bombshell by lecturing on fusion at Harwell. He detailed Russian experience as no other government has: Temperatures up to 1-million° C have been achieved in 40-million-kw peak-power deuterium-gas discharges. Doing this required currents up to 2-million amperes at several tens of kilovolts. Neutrons were observed, but these he attributed to an artifact, rather than true *d-d* fusion reactions. Looking ahead, Kurchatov said success will depend on getting discharge to make many oscillations before it strikes walls; prospects for this look dim, but are being pursued. Striking a new note he said " . . . other interesting possibilities are those in which the idea of stationary processes may be used." All previous thermonuclear conjecture has involved pulsed discharges. The British were very impressed by Kurchatov. He answered questions brilliantly, left U. K. scientists wishing they could talk about their fusion research. U. S. AEC must also remain silent under its own declassification guide, which prohibits discussion of progress or approach. Earlier, AEC had dashed hopes raised by a Swiss newspaper (*Tribune de Genève*) which reported that fusion power had been realized on a laboratory scale in the U. S. Amasa Bishop, chief of the controlled thermonuclear branch of AEC, told NUCLEONICS: " . . . there still has been nothing in the nature of a breakthrough which would warrant anyone's assuming that the program is anything but a long-range project . . . The statements made by Chairman Strauss at Geneva last August are still valid."

$295-Million Capital Funds Voted AEC by Congress

AEC is on the way to getting what it wants in the way of construction money this year. Congress voted, and the President endorsed, a bill authorizing AEC to spend $295,495,000 for plant and equipment in fiscal 1957.

Here's a breakdown on how AEC plans to spend these funds—when and if Congress actually votes the money:

- $113-million for reactor development, both military and civilian. This includes $55-million for a ground-test plant in Idaho for a nuclear-powered airplane, plus funds for additional thermonuclear test facilities;
- $70.6-million for additional weapons facilities;
- $57-million for improvements to existing fissionable materials production facilities;
- $28.6-million for physical research facilities;
- $3,235,000 for raw materials facilities, including $2.8-million for access roads to mines, and $400,000 for laboratory facilities;
- $400,000 for a medical laboratory;
- $554,000 for community facilities;
- $1,117,000 for office buildings;
- $21-million for miscellaneous construction.

AEC had not asked for new construction money, because it had sufficient carryover funds from previous years. But the 1954 Act requires the agency to come in each year and ask Congress for authorization for each construction project.

When he presented his fiscal 1957 budget estimate to Congress in January, President Eisenhower listed planned expenditures as 1. $24.5-million for reactor development and 2. $2.6-million for community facilities.

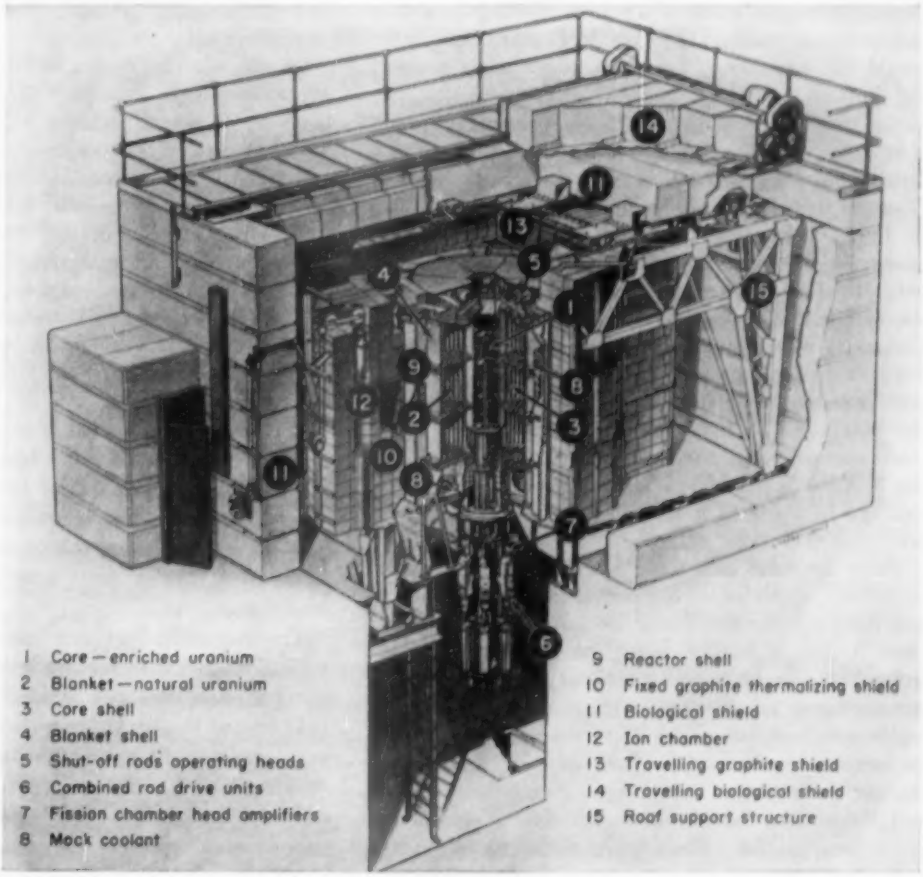
Sodium-Cooled Power Pile Is British Hope by 1960

In London, Britain's Atomic Energy Authority disclosed it is designing a 100-Mw sodium-graphite power reactor, smaller and cheaper than the Calder Hall CO_2-cooled type and using slightly enriched uranium, for incorporation in the U. K. nuclear power program early in the 1960's.

AEA said design work is not yet complete and that the first reactor of the liquid-sodium-cooled type cannot be completed before late 1959.

The announcement evoked some surprise here, as the government White Paper of a year ago outlining a 10-year program of building nuclear power stations had been divided into four phases: the first phase was to use Calder Hall model reactors, the second and third were to be gas-cooled also but with improved heat rating, and only the last

BRITAIN'S "ZEUS"—or Zero Energy Uranium System—is in fact the critical assembly for, and in most respects a full-scale model of, Britain's first fast-breeder power reactor now under construction at Dounreay in northern Scotland. Zeus, of which this is the first sketch released, has been in operation at Harwell for several months. It will operate at a power level of only 100 watts (the Dounreay plant for which it is the prototype will produce 60 Mw of electricity). The core is a cylinder about 20 in. in diameter and 20 in. long, of very highly enriched uranium; surrounding it is a blanket of natural U. Critical mass was found to be very close to predicted value. No cooling is required. Zeus is Britain's second fast reactor: Zephyr, a Pu-fueled pile also at Harwell, is the first



phase—plants begun in 1961–62 and completed in 1965—would pass from gas-cooling to a more advanced approach. "The last four stations might be of the liquid-cooled type which might by then have been developed sufficiently to be economically satisfactory," the White Paper said. The present disclosure therefore seemed to imply research progress far in advance of the timetable.

However this does not seem to be borne out by NUCLEONICS' inquiries in London:

AEA says sodium metallurgy and experimental experiences with liquid sodium are still classified. It emphasizes no final decision covering definite use of sodium has been or can be taken until the Dounreay station has been operating for some definite period. In the meantime light and heavy water and other alternatives to CO_2 may show more promise than sodium. However, design studies have been undertaken of 100-Mw stations using sodium.

AEA points out the possible adoption of liquid-sodium cooling most definitely stems from the shortcomings if not the impossibilities of using CO_2 or any gas cooling system for more enriched fuels using higher temperatures. Heat transfer rates with gas cannot be improved beyond certain values without raising the gas pumping horsepower prohibitively. With D_2O reactors, core size is so reduced that surfaces available for heat transfer become too small to use gas heat transfer.

In the Central Electricity Authority's program, the last four of the 16 reactors are likely to be sodium-cooled with graphite moderators; twelve others use CO_2. But no final decision has been taken on pile design or electrical output of sodium-graphite units. The use of sodium cooling still depends absolutely on experience gained with the experimental Dounreay installation, a sodium-cooled fast reactor of 60-Mw capacity, due for operation in 1959. A prototype (see cut) is now running at zero energy at Harwell.

Sodium remains most likely at this moment but light and heavy water systems are still under intensive investigation.

Washington Report

While the Maritime Administration was getting support—in the form of dollars-and-cents construction bids from industry—for its contention that a nuclear-powered tanker that could be built starting tomorrow would come close to competing with a conventional tanker, the prospect that Congress would vote the money for it was nevertheless growing dimmer.

Not that Congress feels the nuclear tanker project is not worthwhile. Rather, it has run afoul of a jurisdictional dispute between two committees. Charged with responsibility for "all matters relating to the development, use and control of atomic energy," the Joint Committee on Atomic Energy has naturally been interested in the nuclear merchant ship. But the House Merchant Marine Committee has taken the position that it will block any legislation it has not passed on. Although its pride is involved, the Merchant Marine group also makes the point that as nuclear energy comes more and more into everyday use in a great variety of fields, the JCAE will put half of all congressional committees out of business if it continues to keep a tight hold over everything atomic.

There are nine bills for a nuclear merchant ship in various stages of consideration in this Congress, and there are three different nuclear ship proposals. One is for a tanker using present-day reactor technology—an improved *Nautilus*-type pressurized-water reactor minus combat features. Second is a longer-range project to develop a reactor specifically for merchant marine application, using a closed-cycle nuclear gas turbine. These correspond to Phase 1 and Phase 2 of the Maritime Administration's program (see p. 73). Then there is the Eisenhower "peace ship" proposal which Democrats have attacked as a "showboat," a "carnival ship," and which the Merchant Marine Committee spurns as a nonworking merchantman, diverting scarce nuclear technicians without advancing the art of nuclear merchant ship propulsion.

Of the nine bills, two rival ones backed by the vying committees have been partially acted on. One by Rep. Herbert C. Bonner, chairman of the House Merchant Marine Committee, passed the House last July but has not been called up in the Senate. The other is by Sens. Magnuson, Anderson and Clements (Magnuson is head of the Interstate and Foreign Commerce Committee, Senate counterpart of House Merchant Marine; Anderson is head of JCAE); this bill has been favorably reported by both JCAE and Senate Interstate Commerce, but was twice passed over on the calendar by the Senate, last August and again this March.

A further complication is that the Maritime Administration contends it has blanket authority under the Merchant Marine Act of 1936 to build a nuclear or any other kind of merchant ship, and requires only an appropriation; the House Merchant Marine Committee says it must first authorize such construction.

The current budget now before Congress contains a $22.5-million item for Maritime to build a nuclear merchantman; late last month, this item was withheld by the House Appropriations Committee pending further study, out of courtesy to Bonner. This effectively kills the project for this year unless sufficient pressure is put behind a new try in a supplemental appropriation bill.

Clifford Beck to Help AEC Set Safeguards Procedure

Clifford K. Beck, head of the physics department at North Carolina State College and designer and supervisor of the first university-owned research reactor, is taking a year's leave of absence starting June 1 to help shape AEC's reactor safety program. His title will be scientific adviser to the director of civilian application, and he will "assist in developing criteria and standards for the safe design and operation of atomic reactors and other nuclear facilities, and in the safety evaluation of individual facilities proposed to be constructed either by the Commission or by private enterprise under license."

AEC plans to relieve Rogers McCullough's long-overburdened Advisory Committee on Reactor Safeguards of the chore of making reactor reviews and determinations in individual cases, and free it to perform an over-all study, policy-making and supervising function (NU, Dec. '55, p. 9). AEC's own safeguards staff would then apply Committee-drawn rules for each reactor type to individual reactors. It is this staff that Beck is joining. AEC hopes to get this staff to full strength of 10–15 and ready to take over within a year.

The Commission expressed itself as being lucky to have gotten a man of Beck's breadth of experience. (He worked with the Manhattan District from 1943, later was senior physicist and laboratory director at Oak Ridge, and in 1949 went to N.C. State to pioneer design and construction of the water boiler at the Raleigh campus.) "It's not often you can get a scientist of his caliber with experience running a reactor," an AEC official remarked.

JCAE Has Indemnity Plan

The Joint Committee on Atomic Energy will start hearings May 15 on a legislative proposal for a $500-million-ceiling government indemnity for power reactor disasters. JCAE is asking "assurance from the atomic power industry that if [such] legislation is enacted the [private] program will be accelerated." Earlier Sen. Gore, on the Senate floor and before the American Public Power Ass'n. convention, had demanded a governmental "crash" program of nuclear power development.

About the Industry

Zirconium production expanded. AEC's annual purchases of reactor-grade Zr will rise from 200,000 lb at present to 2,825,000 lb under a vast $14-million/yr program. Three companies (of 12 bidders) got five-year contracts, will build new plants at their own expense. National Distillers Corp. got the lion's share, will supply 1-million lbs of sponge a year at $4.53/lb [present price is $12.05], will use now sodium reduction process at a 1.5-million-lb/yr plant it will complete at Ashtabula, O., by July '57. (The extra half-million lbs will be available to industry.) Not well known hitherto for its part in the nucleonics industry, Distillers' U. S. Industrial Chemicals division is nevertheless a major supplier of pure sodium for liquid-metal cooling systems; it has done much development work on titanium reduction, and plans to bid in AEC's beryllium supply program (NU, Jan. '56, p. 16). Second, National Research Corp.'s NRC Metals division will supply 700,000 lb/yr for $6.50/lb from a new plant near Pensacola, Fla., using a new ammonia-and-nitric-acid purification process. Third, Carborundum Metals Co., at present the only supplier, will furnish an additional 500,000 lb/yr at $7.72/lb from a new plant at Parkersburg, W. Va.; in addition it is increasing the capacity of its present Akron, N. Y., Kroll-process plant from 200,000 to 325,000 lb/yr (NU, Dec. '55, p. 13; Feb. '56, p. 45). Finally, 300,000 lb/yr will come from the shut-down Bureau of Mines pilot plant at Albany, Ore., to be reactivated by Wah Chang Corp. of N. Y. In addition, 200,000 lb will be purchased from Japan this year and next to bridge the gap until the new plants go into production late in 1957.

Esso goes to Battelle. A $750,000 contract for a research program in the Battelle Memorial Institute swimming-pool reactor was signed by Esso Research and Engineering Co. It provides for at least $250,000 worth of work a year for three years in the use of radiation in petroleum refining and in the production of petrochemicals. Battelle scientists will carry out the work in the privately-owned research reactor now nearing completion at Columbus, Ohio. It is understood that Esso found inadequate the 13-in., 3.1-kc Co^{60} pipe it is using at its Linden, N. J., radiation lab and described as the most radioactive piece of material in use by industry (NU, Jan. '56, p. 10); rather than build a specialized reactor of its own, Esso is trying this compromise solution.

Sylvania tooling up for nuclear-fuel service. A five-year, multi-million-dollar expansion was announced by the Atomic Energy Division of Sylvania Electric Products. First step will be construction by 1957 of a new production plant and laboratory, on "one of several sites under consideration in the East," to develop and turn out nuclear fuels and components. It will be financed entirely by the company. The expansion program encompasses the company's previously-announced plan to provide "diaper service" on reactor fuels—a "complete and integrated fuel and reprocessing service."

Fairchild off to good start. The nuclear instrumentation activity organized only a few months ago at Fairchild Camera and Instrument Corp. is already receiving production contracts for control devices. The AEC-Westinghouse Bettis plant, builder of the *Nautilus*' reactor and now working on improved submarine engines, ordered quantity of valve-position indicators and detectors.

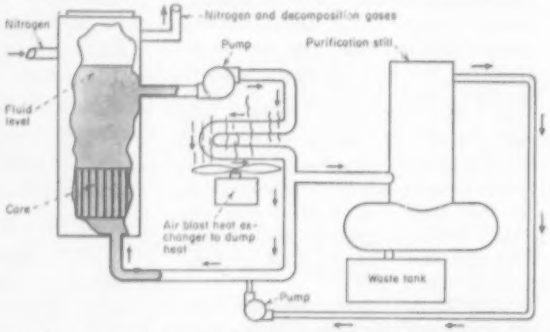
Reactor News

U. S. A-plane progress on four fronts. The nuclear-powered airplane was much in the news last month as the Air Force moved in four directions to intensify its work on the top-secret project: **1.** It will build a runway 15,000 ft long at the National Reactor Testing Station at Arco in the Southern Idaho desert. **2.** It awarded a new contract to General Dynamics' Convair division for continued development work on an airframe for a nuclear plane at Convair's Fort Worth plant. There Convair has been working on the project since 1951, when it was awarded the first Air Force contract for development of an airframe for a nuclear plane. **3.** Another airframe development contract went to Lockheed Aircraft Co. of Burbank, Calif. Lockheed will erect a multimillion-dollar laboratory and development facility on a 10,000-acre tract of rugged mountain country near Dawsonville, Ga., 60 miles north of Atlanta. The facility will be owned by the government and operated by Lockheed; several hundred engineers and scientists will be employed. **4.** Finally, the Air Force's Air Research and Development Command will start construction in June of a $7.5-million-plus test and research-reactor facility at its Wright Air Development Center, Dayton, Ohio. The 10-Mw facility, to be known as the Air Force Nuclear Engineering Test Facility, will be used to test aircraft materials, components and systems under development; it is to be completed by January 1958. A water-moderated and -cooled pile described as being "similar to the MTR" but also incorporating "two large irradiation test cells, a swimming-pool-type bulk shielding facility, a spent-fuel storage well and a number of conventional nuclear-reactor facilities," it will apparently most resemble Oak Ridge's LITR plus a 125,000-gal pool on one side. The entire reactor complex will be housed in a gastight domed cylindrical steel containment shell set partly below ground. The facility also will include: an adjoining test reactor building containing control rooms, offices and test areas; a high-level-radiation building, a waste storage and treatment plant, a two-story engineering laboratory, a demineralization plant, a cooling tower to dissipate 35-million Btu generated by the reactor each hour, and water storage facilities. The design was completed and formal invitations to bid issued late last month; these will be opened June 14, and a contract let June 24.

French start work on nuclear flight. Two years after the government announced plans to construct a nuclear plane engine, the first step has been taken toward implementation: one of France's airplane builders, SNECMA (Société Nationale d'Etude et de Construction de Moteurs d'Aviation), has set up a nuclear engine division at its Suresnes plant on the western edge of Paris. It is headed by Raymond Marchal, SNECMA's chief engineer and one of France's leading aviation technicians; he had spent the last 18 months at the Saclay nuclear research center studying latest developments. The company declines to give details on the direction its research will take, except to say it would "probably not work along the same lines as the Americans."

Core for Yankee. Details on the slightly-enriched uranium core for the proposed Rowe, Mass., pressurized-water reactor were disclosed by Yankee Atomic Electric Co. The pressure vessel will be a cylindrical steel tank 9 ft in diameter, 23 ft high, with walls 8 in. thick lined with stainless steel. It will be enclosed in another water-filled tank 15 ft in diameter with concrete walls 8 in. thick, lined inside and out with steel plate. Outside this will be a 50-ft-diameter vapor shield of steel and concrete. The pressure vessel will be filled with water in which the fuel elements will be immersed. The elements will be stainless steel tubes 0.4 in. in diameter and 6 ft long, so arranged that +-shaped control rods may be slid between them. The tubes will be packed with cylindrical capsules $\frac{3}{8}$ in. in diameter and length, composed of slightly-enriched uranium oxide in powdered form. Water in the pressure vessel will be heated to 560° F under 2,000 psi, and will return from the heat exchanger at 510°; the secondary will make 600-psi steam.

Details on OMRE. The adjoining diagram of the Organic Moderated Reactor Experiment, which Atomics International (NAA) is designing and building at Arco for the AEC, shows what is involved in the small experimental unit. The core consists of plate-type fuel elements containing highly-enriched uranium. A liquid organic compound such as diphenyl serves both as moderator and coolant. The still at the right serves to purify the organic for re-use in the reactor. About 16-Mw of heat will be produced but will be exhausted



to the atmosphere through an air-blast heat exchanger, as the experimental program is concerned only with the technology of using organic liquids in a reactor. Problems outstanding concern chiefly the effect of heat and radiation on the organic coolant, which has a tendency to dissociate and in so doing to foul the fuel elements; but AEC and AI are optimistic that this problem can be solved. Primary purpose of OMRE is to determine the radiation and thermal stability of organic coolants under reactor conditions. Use of an organic compound offers several advantages: high hydrogen content makes it an excellent moderator; a much higher boiling point than that of the water means higher thermal efficiencies are possible and high pressure is not required; corrosion with standard structural materials is negligible; it does not react readily with uranium, and becomes only slightly radioactive on irradiation. OMRE will cost $1.8-million, of which AI is bearing $750,000. AI is also design agent for the city of Piqua, Ohio, which proposes building a 12.5-Mw organic-moderated power reactor if the OMRE is successful.

New reactor design firm in England. Still another British company to design power reactor units for both cargo ships and central stations (NU, April '55, p. 23) has been set up—Richardsons Westgarth Atomic, capitalized at $700,000. According to NUCLEONICS' London bureau, British experts expect "several prototype nuclear-powered ships to be in operation by 1965, and "a fair number of merchant vessels" by 1970.

World News

Satellites centralize nuclear work. Soviet-dominated East European countries have joined in a "Central Institute for Nuclear Research." Members so far are Czechoslovakia, Hungary, Poland, East Germany and Rumania. Headquarters of the institute are in Moscow. Other countries have been invited to join, including Soviet satellites in the Orient. The U. S. S. R. has transferred to the new Central Institute both the Soviet Institute of Nuclear Physics Science with its 680-Mev synchrocyclotron, and the electrophysical laboratory of the Soviet Academy of Sciences with a 10-Bev synchrotron and much auxiliary equipment. Other Soviet-bloc news: Hungary and Rumania are now conducting medical research with radioisotopes supplied by Russia. Poland has begun publication of a magazine dealing with nuclear subjects; it is called *Nucleonika*. Moscow reports it has made the barium atom visible with a new electronic projector giving 10-million magnification.

India sketches five-year-plan. The Nehru cabinet has accepted a nuclear development plan submitted by India's AEC. It includes some projects announced earlier, such as the swimming pool reactor to be completed this year at Trombay, India's nuclear center near Bombay; the Canadian-built NRX-type reactor, also at Trombay, for completion in mid-1958; a heavy-water plant at Nangal in the Punjab, and expansion of the rare-earth treatment plant at Alwaye in Travancore-Cochin. New items include further expansion of the U-Th plant at Trombay; erection of a plant using solvent extraction to treat impure U extracted from monazite at the metal stage; a pilot plant for titanium sponge from native rutile and ilmenite sands (negotiations with National Lead Co. are in progress on this); and a multi-million-dollar prospecting program for nuclear raw materials. The program envisages employment of 800 Indian scientists by 1958 in the physics and chemistry branches alone. It also lays down that while fuel elements for the swimming pool will come from Britain and D_2O moderator for the NRX from the U. S., all future development should be on the basis of indigenous material supplies.

Brazil front-runner for an A&FP power plant. "Everything is set but the final details—all previous objections have been ironed out" regarding Brazil getting one of the three 10-Mw power reactors American & Foreign Power Co. plans to put up in three Latin American Countries (NU, March '56, p. 22; Dec. '55, p. 16). So reports NUCLEONICS' Rio correspondent. The objections had come from a nationalistic minority, "singularly uninformed" on nuclear fundamentals, in the National Research Council who wanted a breeder using native thorium. One remaining problem is location: logical spot is São Paolo, Brazil's industrial and scientific center; but President Kubitschek, former mayor of Belo Horizonte in Minas Gerais state, wants it for his home town.

One of the first four countries to begin implementing their research bilaterals (NU, April '56, p. 17), Brazil is the first to find out exactly what is to be had under the President's generous but vague offer in his Penn State speech last June whereby the U. S. would pay half the cost of a research reactor for friendly countries (NU, Dec. '55, p. 10). Brazil will get a U. S. contribution of $350,000 toward her 5-Mw Babcock & Wilcox swimming-pool reactor. Meanwhile it is also learned that Brazil has two power projects going: in addition to the A&FP project, Rio would like a Shippingport-purpose power unit: i.e., one run not so much as a straight commercial venture as to learn power technique, get operating experience and train personnel. This would also be about 10-Mw, and would be a thorium converter. The draft of a power bilateral (see p. 17) specifically provides that Brazil is to have access to available U. S. data on thorium.

U-Mill for Sweden. W. H. A. Robertson & Co. Ltd. of Bedford, England, has received an order from the Swedish Atomic Energy Authority for a uranium rolling mill. Robertsons built the first such specialized mill in Britain, is making several more for the U. K. AEA.

UK increases funds 26%. Atomic Energy Authority funds for fiscal 1956 will total $191,240,000, an increase of $39,480,000 over last year according to budget figures. Most of the increase will go for new nuclear plants and equipment; $44.24-million is to be spent on new plants, of which $7-million is for plants to be started this year. Total cost of work started this year will eventually reach $32.76-million. Plant and machinery expenditures will be $56-million, as compared with $36.68-million in fiscal 1955. Government loans to the Authority for financing U and D_2O production will total $13.44-million, up from $10.92-million; part of this amount will probably be spent on purchase of 50 tons of D_2O from the U. S. for $3-million. Meanwhile, the Authority reports that the "A" reactor at Calder Hall, to be officially opened Oct. 17, is now ready for fuel-loading. Also, construction of the $84-million nuclear power station at Chapel Cross near Annan in southwest Scotland is underway. The four-reactor station, due to be completed in 1959, will produce 200 Mw of electricity as a by-product; primary purpose is plutonium production. The reactors are basically copies of the Calder Hall design but embody some improvements. Presently 700 workers are employed on the 100-acre site, a former airfield.

The man in the red flannel suit. A six-man Soviet technical mission visiting the Arab countries has offered Egypt "all the uranium Egypt wants for peaceful uses." The mission is headed by Nikolai Melnikov, chief of the Soviet Techno-Export organization, who signed the recent agreement with Egypt for setting up a nuclear physics laboratory; he said four Russian experts would soon come to Egypt to set it up. He added the USSR would help Egypt look for uranium on her territory, and would supply it if none were found. He said Techno-Export had no political motives and attached no strings to its aid.

Britain may ask U. S. for enriched uranium. Deputy Prime Minister R. A. Butler hinted in the House of Commons that Britain may seek a supplementary source of enriched uranium in the U. S. Britain, as a nation having its own enrichment facilities, is excluded from the recent U. S. offer of 20,000 kg of U^{235} to foreign countries, but her supplies are very limited. Negotiations for a separate agreement between the two countries are said to be underway.

Industry encouraged in Canada. Atomic Energy of Canada Ltd. has established an industrial assistance office at Chalk River to encourage industry to take a more active part in nuclear development.

Nuclear graduates in France. For the first time in France, 22 engineers were handed diplomas in nuclear engineering after completing a one-year course at the Saclay nuclear research center; 42 are in the next class.

ROUNDUP

News in Brief

When you eat chicken you can't tell the difference. This was the word Ralph G. H. Siu, technical director of research and development for the Army Quartermaster Corps, brought to a panel on food irradiation. Chicken, pork, shrimp, and fried oysters are not at all affected taste-wise by irradiation, and QM tasters couldn't distinguish fresh, quick-frozen, and irradiated samples. On beef, the testers disagreed; milk still gets a bad off-flavor. But some process cheeses actually improve in taste, come out tasting like expensive smoked cheese. The government is conducting basic research in this field because the cost is prohibitive to the food industry, Siu said. Preliminary results now have QM thinking in terms of commercial food irradiation arriving in 10 years. QM's testing program is now emphasizing research on foods adversely affected by irradiation.

JCAE hears views on nuclear education. Rep. Melvin Price's Congressional subcommittee on nuclear research and development called in a panel of authorities to discuss the crisis in educating scientists and engineers. General Advisory Committee chairman I. I. Rabi suggested nationwide exams for high-school seniors taking math, with a large number of $500 scholarships for the best performances serving to interest more students in taking up math. David Sarnoff urged—as Admiral Rickover has also done—that companies donate the services of their top scientists for one-year periods to act as school and college teachers.

Design contracts for Vitro. The engineering firm is understood to be completing negotiations to handle overall design of nuclear facilities. Reportedly, these include the new Lockheed nuclear aircraft layout in Georgia (see p. 22) with two reactors—one of them on a high tower—and a large lab; a nuclear facility for General Electric at its Evendale, Ohio, nuclear plane plant; two reactor projects at Ft. Belvoir, Va., one of 2 Mw, another of 20 Mw; and Con Ed's Indian Point plant for B&W.

Electron accelerator for Cambridge. Harvard and MIT will jointly design, build, and operate a 6-Bev electron accelerator (instead of as in NU, April '56, p. 24). The machine will cost about $6.5-million of AEC money, and will be completed in four years.

Polymer research in U. K. Monsanto Chemicals of England has opened a new polymer research lab, the only industrial radiation research lab in Britain, to investigate chemical reactions promotable under beta and gamma radiation, with emphasis on development of plastics.

Advanced medical course at ORINS. Oak Ridge Institute of Nuclear Studies will offer a four-week advanced medical course covering these topics in separate one-week units: Uses of radioisotopes in hematology; general medical uses of radioisotopes; supervoltage and gamma-beam therapy; external radioisotope measurement techniques.

New radiobiology lab. Nuclear Science and Engineering Corp. has built a new laboratory near its Pittsburgh headquarters to house its department of biology and medicine.

Hydro power still judged best in Northwest. On the basis of a study of power costs for both hydro and nuclear projects in the Pacific Northwest, economics professor Kenneth M. McCaffree of the University of Washington concludes that continued development of hydroelectric sites is still best bet for that region. However, although capital investment costs still favor hydro development, he said the rate of reduction of nuclear power costs could be so great that utilities might find it wise to postpone expansion decisions for a few years. After 1970 a significant part of base-system needs in the Northwest will probably be met from nuclear sources.

New lab at LASL. Los Alamos Scientific Laboratory nears completion of its five-year building program to move facilities and personnel to a new technical area divorced from the community of Los Alamos across the canyon. Last month personnel were moving into a new $5-million, 560-office administration and laboratory building that will house in its four stories 1,000 members of the administrative, engineering, test and document divisions.

Radiation-resistant lubricant developed. Because conventional lubricants deteriorate excessively when exposed to radiation, oil companies have long been working to develop lubricants that can function effectively in nuclear engines for shipboard or aircraft use. Standard Oil Co. of California last month announced development of a synthetic "poly (propene oxide)"-type lubricant that actually performs better when under irradiation. It was tested successfully on machinery operating inside the Oak Ridge X-10 pile.

National uranium conference next month. More than 400 are expected to attend a meeting on "Uranium and Atomic Industry," which the Atomic Industrial Forum, jointly with Denver Research Institute, is sponsoring June 25 and 26 in Denver. The conference will bring leaders of the nucleonics and mining industries, finance, government, and education together in the heart of the uranium producing area for the first time. It will cover uranium geology, exploration, development, mining, processing and industrial demand as well as legal aspects and competing energy sources. A two-day tour of mines and mills on the Colorado Plateau will follow.

Reactor for Georgia Tech. Georgia's Gov. Marvin Griffin appropriated $300,000 to Georgia Tech to inaugurate a program of education and research in nuclear science. The money will be used to build and equip a radioisotope laboratory and to set up a graduate training program for nuclear engineers and scientists. In addition he said he would ask the Legislature to approve construction of a $3-million reactor "big enough for industrial and commercial research uses."

Nuclear workers are good risks. Of more than 150,000 employed in atomic energy plants throughout the U. S., at least 99.7% are considered standard risks for life insurance requiring no extra premium due to any atomic hazard, reports the Institute of Life Insurance. Both frequency and severity of accidents in nuclear plants have dropped to ⅙ or ⅒th of 1943 rates, and are today well below those in the petroleum or chemical industries, for example.

New radiation-protection committee formed. Lauriston S. Taylor, chairman of the National Committee on Radiation Protection, announced establishment of a new subgroup on protection from high-energy electrons, to deal primarily with very-high intensity electron radiation from accelerators. Lester Skaggs, of Argonne Cancer Research Hospital in Chicago, is chairman.

RCL Mark XX Multi-Channel Analyzer

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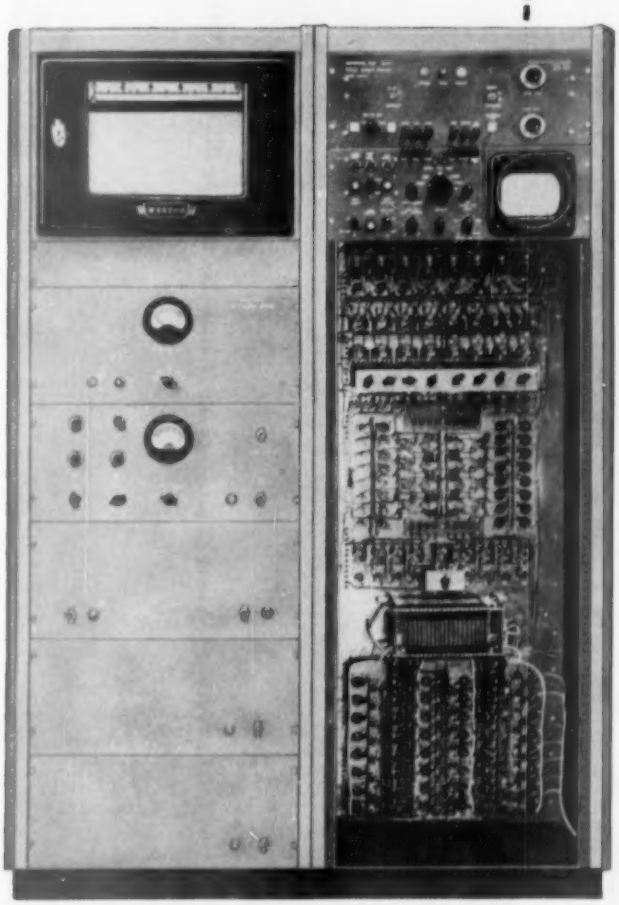
A 256 Channel Analyzer based on the Argonne National Laboratory Design



- Permits automatic subtraction of background from the spectrum read out.
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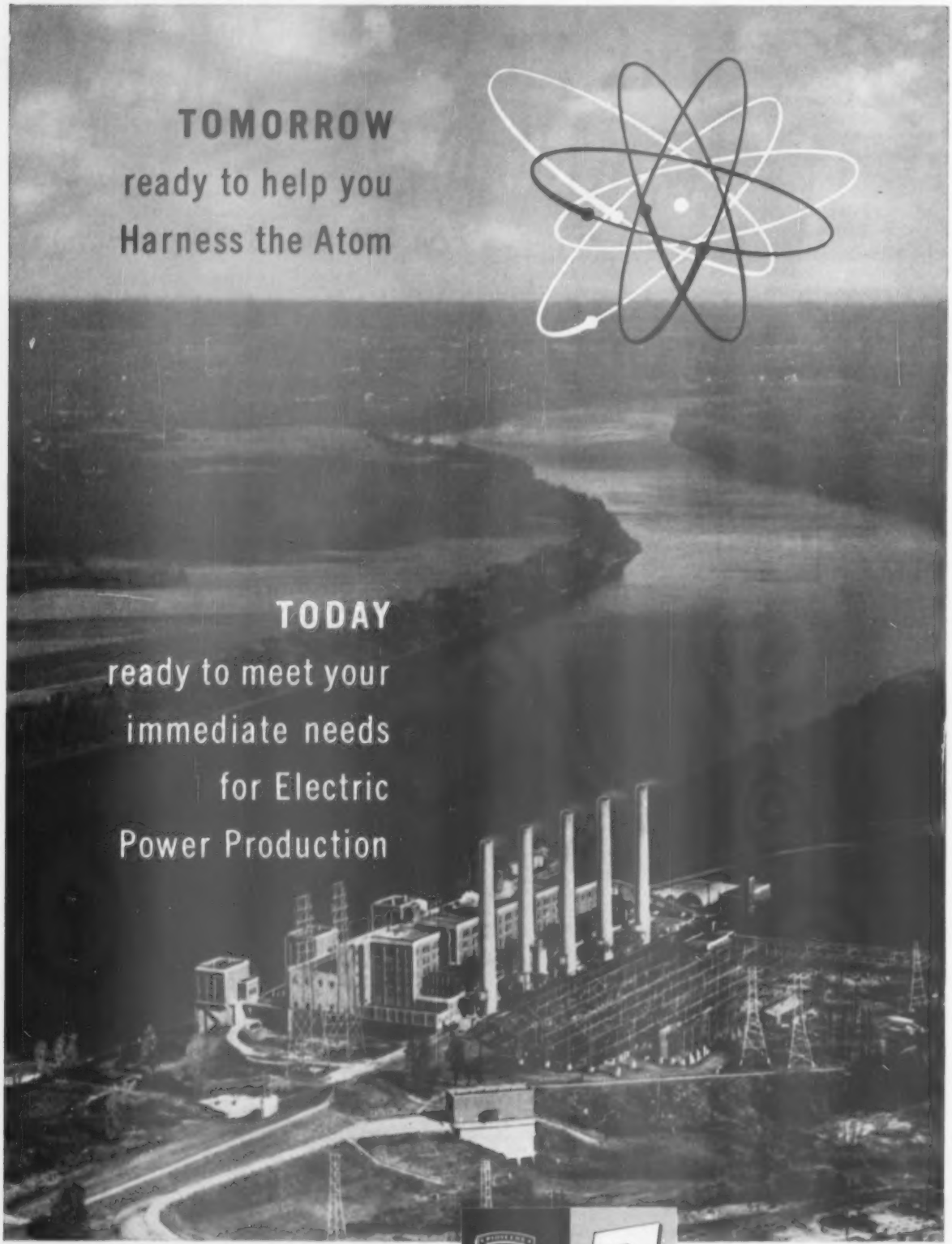

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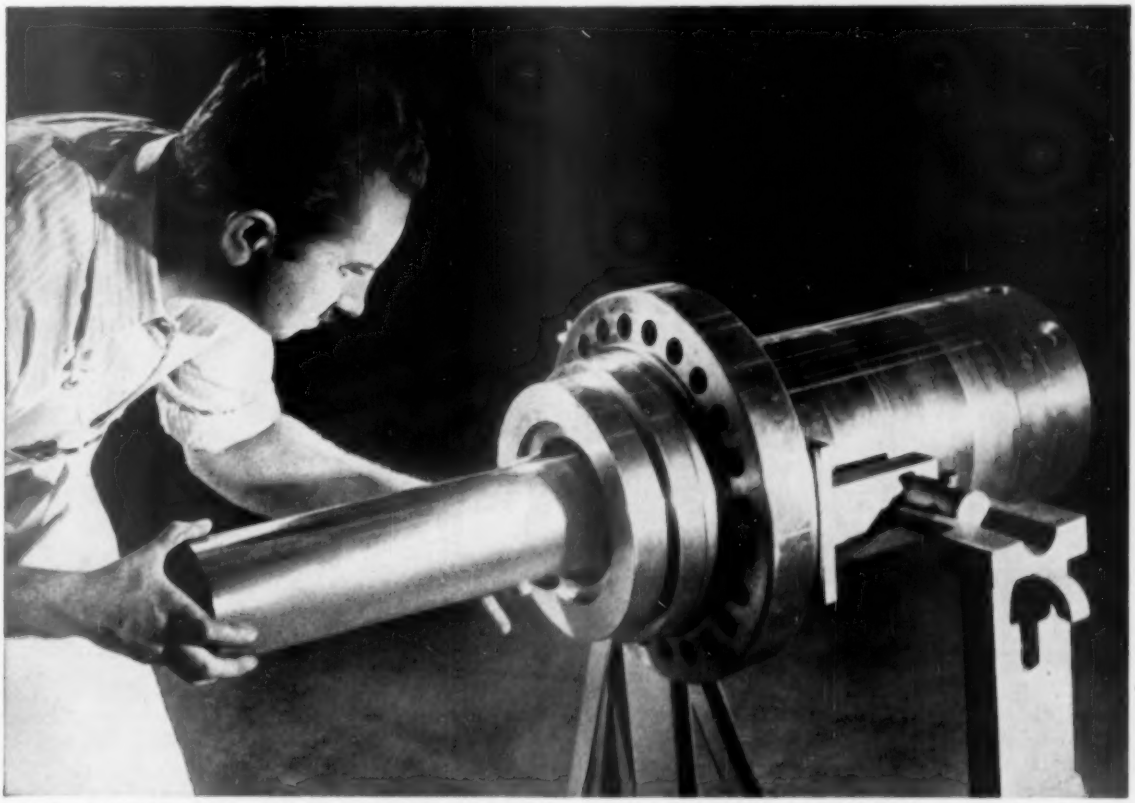

Inconel helped designers lick induction motor operating problem. This Inconel nickel-chromium alloy cylinder lines the bore of the stator, and another surrounds the rotor core . . . literally "canning" each. Yet there's no interference with magnetic fields. The motor was developed by Westinghouse Electric Corporation for the U. S. Government.

Inconel an essential in the "canned" pump

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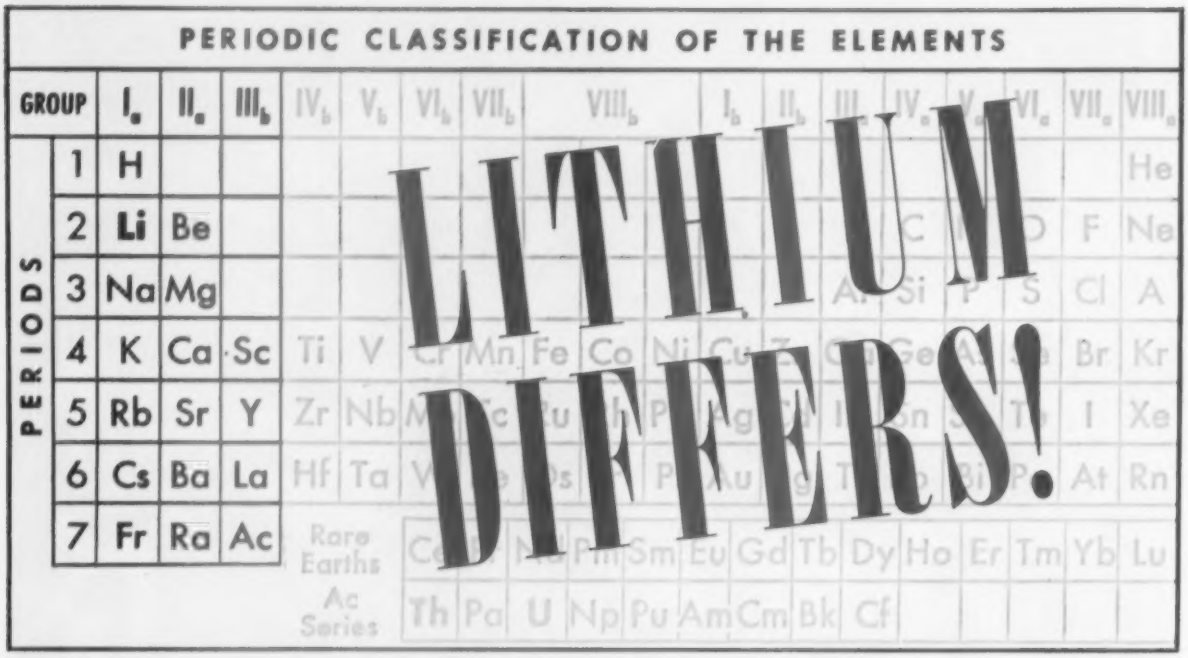

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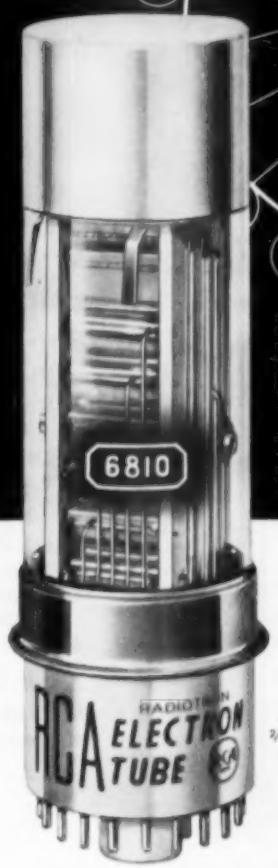

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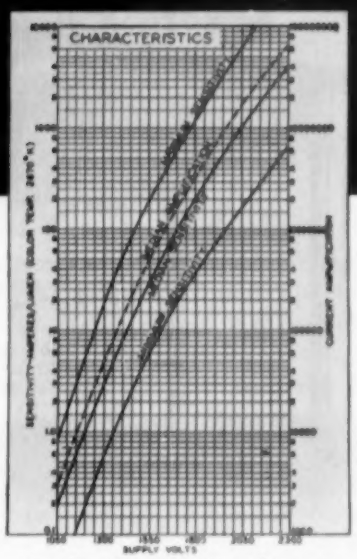

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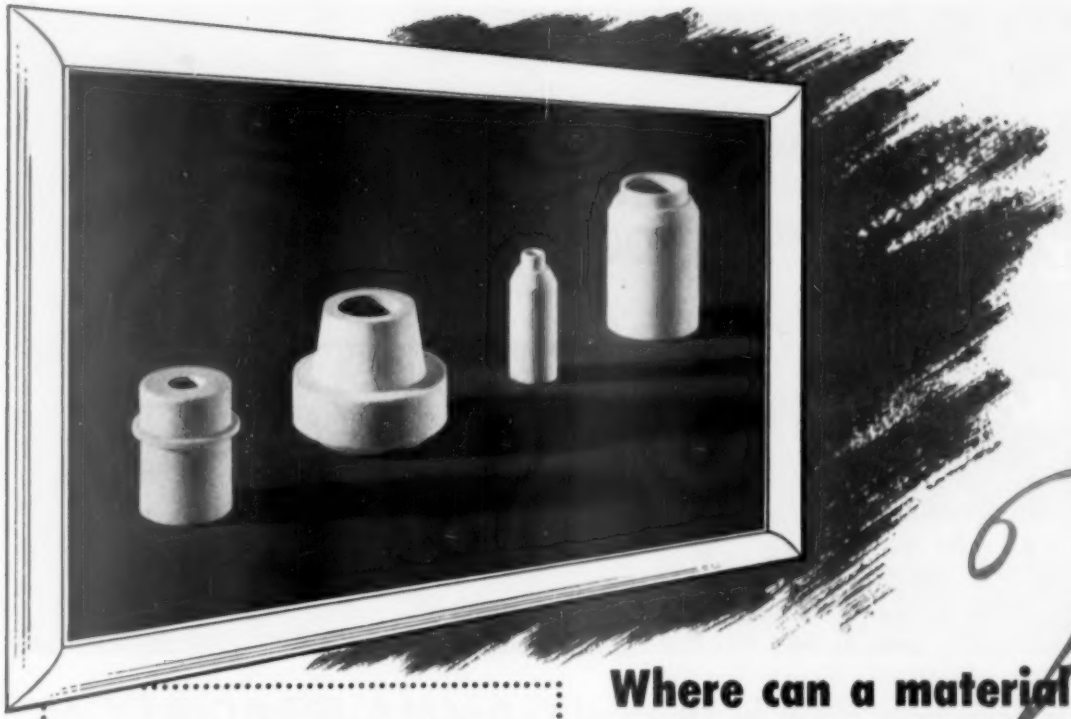

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	@ 1,000 mc	0.0006
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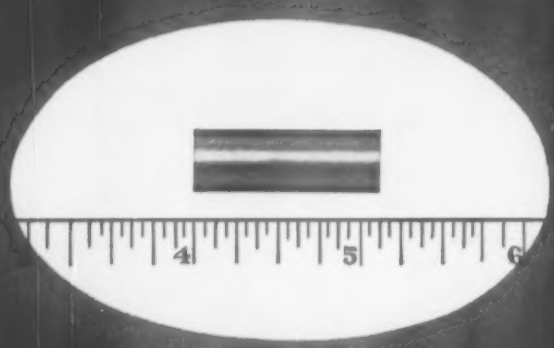

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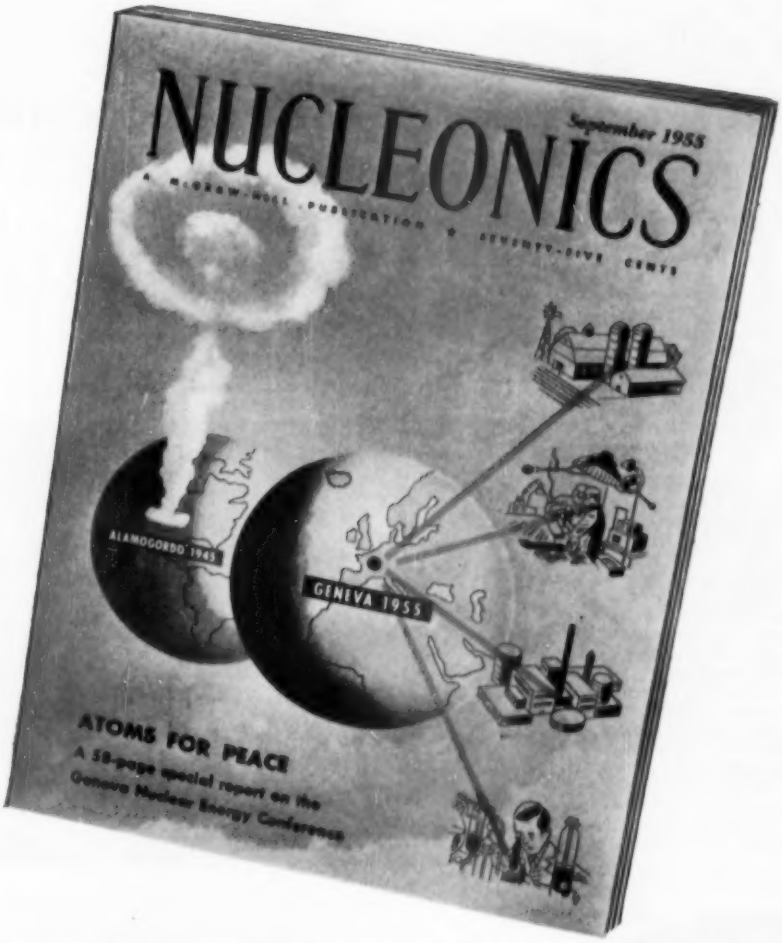

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NUCLEONICS MAY, 1956

Jerome D. Luntz, *Editor*

Nuclear Accidents Are Everybody's Business

LAST November 29, the world's first breeder reactor—EBR-I—was badly damaged in an accident in Idaho. Four months later, amidst much confusion and after being prodded by the press, the Atomic Energy Commission announced that such an accident did in fact take place.

It may be that this delay in the issuance of a press release did harm to the development of the nuclear industry. Without the benefit of facts, some people had already come up with erroneous impressions of the implications of the accident. In fact, the first press stories—before AEC's announcement—gave the impression that the accident was going to be a setback to industry's already difficult task of trying to get ample insurance on nuclear facilities.

The facts actually point in the reverse direction. First, the reactor is an experimental one that was being pushed to high power levels with part of its control system disconnected. Then, when the accident did take place, there was no damage whatever outside the building, and the same would have been true even if the reactor were located in the center of a major metropolis. And it's this question of insurance coverage for third-party liability—damages outside the plant—that is the problem for industry.

WITH these as the facts, why then did AEC not issue a press release immediately? The excellent release that was finally put out would have immediately forestalled the possibility of any misapprehensions. People would have readily accepted the incident as a minor, unfortunate accident with no wide significance—and not nearly as bad as many accidents that take place in conventional industry.

But Commission personnel apparently felt that this was an internal matter and wasn't the business of anyone else. Actually there never has been any question and there never will be but that nuclear accidents are everybody's business. This will always be the case in any industry that has major potential hazards. And we're sure no one's deluding himself into believing that because the nuclear industry safety record has been so superb hazards aren't potentially great.

Evidence of the universal interest in radiation safety—and, obviously, in nuclear accidents—is not difficult to come by. First, the character of atomic energy is such that one of its drawbacks is the harmful effect that its use can have on others. There are radioactive wastes, including solid, liquid and gaseous effluent from reactors. There is the possibility of major reactor accidents. There are the dangers of transporting radioactive and fissionable materials between cities, between states and between countries.

Because of this universal interest in the effects of nuclear radiation, we in this country have taken very great precautions. Various Federal agencies, state groups, insurance bodies, the National Committee on Radiation Protection and others have concerned themselves with the problem. The same is true in other countries.

IN this the infancy of the nuclear industry, it's important that full information be issued promptly on any nuclear accidents. It's serious enough that a bad nuclear accident almost anywhere in the world today would have a retarding effect on the development of the industry. But because attitudes toward hazardous things are so frequently conditioned by psychological factors, misinformation or incomplete information about a minor nuclear accident could have almost as retarding an effect as a major accident.

And in the case of the Atomic Energy Commission, there is little question that because AEC has been and still is the primary generator of nuclear experience and because AEC is operating on the frontiers of this new technology, AEC experiences will come under much closer scrutiny and evaluation than those of others.

Apart from the bad effect that secrecy would have on attitudes toward nuclear safety, such withholding of news is wrong in principle. It is beyond the authority of AEC to withhold information not affecting the national security. And because AEC operates in so much secrecy, public confidence in it will surely be undermined.

Thus, for the sake of the most expeditious development of a peaceful international atomic energy industry, the U. S. Atomic Energy Commission must in the future recognize that the eyes of the world are on it. Nuclear accidents are, indeed, everybody's business. We hope none will ever happen again, but if they do, AEC must, on its own initiative, promptly issue a statement of the facts.

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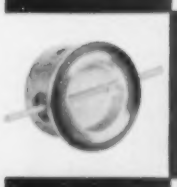

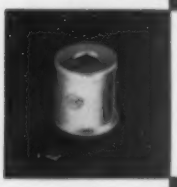

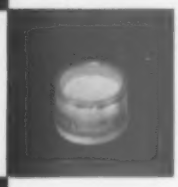

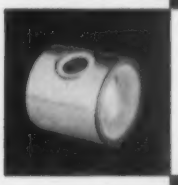

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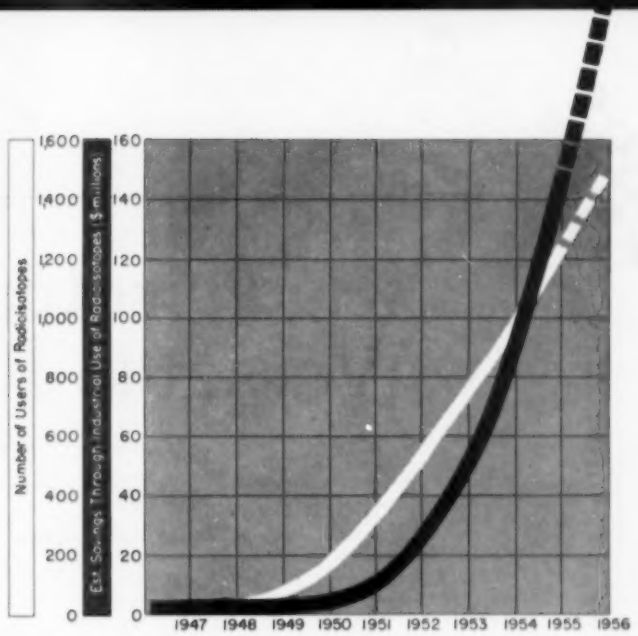

A SPECIAL REPORT

Applying Radiation in Industry

Despite the fact that radioisotopes have been in wide use since 1946, it is only in recent years that their use in industry has become significant. There are now some 1,400 industrial groups routinely applying radioisotopes to their research, analytical, process control, and production problems.

Although any estimates are admittedly rough, it has been calculated* that in 1955 industry saved $150–200-million through the use of radioisotopes and that these savings may grow to $1-billion annually in the next decade.

Because of the obvious tremendous importance of radioisotopes to industry, NUCLEONICS has prepared this special report to point up the advantages and techniques of applications that have been particularly successful. Emphasis is placed on why experiments have been planned in a particular manner and how optimum results were achieved.

We have had invaluable assistance in the preparation of this report from Dr. Charles E. Crompton, formerly assistant director of AEC's Isotopes Division, and now associate technical director of National Lead Co. of Ohio. The following comment on the report by Dr. Crompton adds useful perspective:

"The reader should bear in mind that the successful planning of an isotope study in one field of endeavor closely parallels the planning and evaluation in an entirely different field. For example, biological or medical tracer studies involve many of the same feasibility considerations as do large-scale industrial tracing. The determination of blood flow through the heart by the technique of integral counting is little different from certain industrial hydraulic tracer studies. Thus, it is imperative that the industrial isotope user be alert to new applications or techniques that develop in other disciplines.

"In a similar vein, one should not lightly discard a potentially valuable isotope use just because the feasibility study reveals that it could not be accomplished economically or safely or sufficiently accurately with today's instrumentation. The unusually rapid advancement of scintillation detection equipment during the past few years clearly illustrates that promising ideas must be reviewed periodically in light of improvements in instrumentation. Tomorrow's instrument may permit you to achieve the required sensitivity with an acceptably safe quantity of radioactivity."

* The estimates for the data on savings by industry were supplied to NUCLEONICS by Dr. George G. Manov, U. S. Atomic Energy Commission, Washington, D. C. The estimate of $100-million savings for 1954, shown on the chart, includes $40-million by thickness gages, $30-million by radiographic testing, and $30-million by miscellaneous radioisotope techniques.

Radioisotopes— Versatile Research Tools

By G. D. CALKINS
Battelle Memorial Institute, Columbus, Ohio

RADIOISOTOPES represent one of the major tools that have become available to the research scientist, but the full potential of these tools has not yet been realized in the fields of research and development.

The majority of research applications are in the field of tracer methodology, in which the location or quantity of a material is wanted. In these applications, advantage is taken of the fact that radioisotopes behave chemically the same as the stable isotopes of the respective elements, and that their radiation indicates their location and quantity. Examples illustrate the breadth and diversity of radiotracing techniques.

Small-Quantity Tracing

Suppose that a very small quantity or concentration of a material is to be traced. For example, in the field of transistor research it was desired to determine the mass transfer of material from a gold-plated tungsten whisker electrode to a germanium semiconductor during the forming process due to a voltage pulse and the distribution of the gold transferred (*1*). A whisker plated with radioactive Au^{199} was pulsed in contact with the crystal. The quantity of gold transferred was found by activity measurements to be a total of about 10^9 atoms, 3.3×10^{-13} gm, into a volume of 10^{-7} cm^3 of the crystal. As shown in Fig. 1, the distribution was determined autoradiographically at different depths in the crystal by lapping off thin layers and exposing a photographic emulsion to the exposed surface. The transferred gold was found distributed in a conical shape with a base about 100 microns in diameter and an apex about 2.5 microns into the crystal.

Nonseparable Materials

Sometimes the material being traced is associated with other materials difficult to separate from each other. For example, in the drawing of steel wire a lime residue from the liming tank or lubricant may interfere with the subsequent coating of the wire. A study of the cleaning of the wire by conventional analytical techniques is extremely difficult because the separation of the very small amounts of lime on the wire is required. The use of lime labelled with the radioisotope Ca^{45} permits the detection of a lime residue of as little as 2.5×10^{-6} in. thickness without the necessity of making a complete chemical separation of the calcium from a large amount of the components in the steel wire (*2*).

Nondestructive Testing

Perhaps a sample must be analyzed nondestructively or in place. For example if the piston rings in an internal combustion engine were designed to rotate, wear would be evener. In the testing of this system it was difficult to determine the rate of rotation of the piston rings once they were installed. By incorporating a small amount of a gamma-emitting isotope at a point along the periphery of a piston ring, it was possible to determine the rate of revolution of the isotope deposit by using a counter located at a point outside the cylinder wall and, therefore, the rate of rotation of a particular design of piston ring (*3*).

It may be desirable to find the position of a material. A study was made of any harmful segregation of intermetallic compounds resulting from rare-earth additions to steel using a mixture of radioactive rare-earth metals known as misch metal. As shown in Fig. 2, autoradiographic and metallographic analyses of microsections of a sample of the tagged alloy were compared to show that misch metal atoms were dispersed throughout the matrix and slightly concentrated in the interdendritic zones (*4*).

A material can be traced in the presence of itself. For example in a study of the migration of moisture into attached protective varnish coatings, it was desired to determine the relative rate of migration of moisture at a relative humidity of 100% into a dry film as compared to that of a film that had been pre-exposed at a relative humidity of 60%. Water labeled with tritium was used for the exposures at 100% relative humidity. The pre-exposure at 60% relative humidity was made with unlabeled moisture. In the dry-film case, in less than 1 hr moisture completely penetrated the particular varnish film being studied and established equilibrium with essentially a uniform moisture content throughout the film. In the case of the pre-exposed film, a uniform concentration of the labelled moisture was not found in the film after a 100-hr exposure. This shows that although the initial migration of moisture into the film is rapid, the exchange of moisture already in the film with atmospheric moisture is relatively slow (*5*).

These cases illustrate some of the

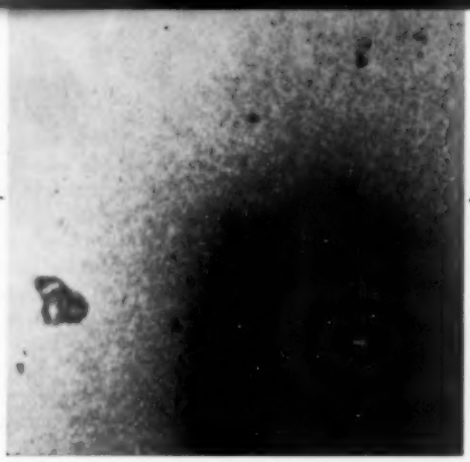

FIG. 1. Autoradiograph of germanium crystal section shows distribution of gold transferred from tungsten whisker

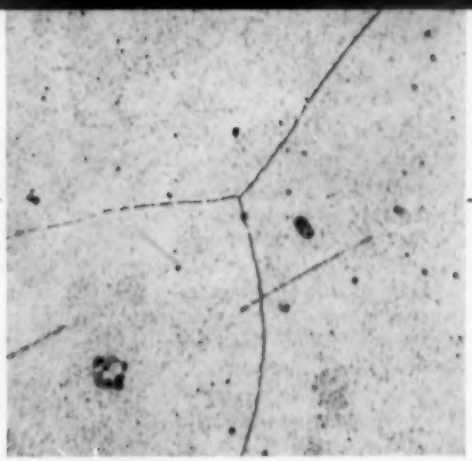

FIG. 2. Superposition of photomicrograph and autoradiograph of steel containing radioactive misch metal

major ways in which radioisotopes are useful to the research scientist and engineer. They are useful research tools that warrant wider consideration as aids to solving problems. An extra dividend is available to those whose acquaint themselves with radioisotope techniques. In all aspects of both basic research and development work there are countless opportunities for radioisotopes to provide unique answers. Research problems of considerable economic import can be approached and solved with this powerful tool—and with an extremely modest capital investment.

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CASE STUDIES

Measuring Adsorption of Cosmetics

By M. F. NELSON, JR.

Colgate Palmolive Co., Wright Laboratory
Rutgers University, New Brunswick, New Jersey

COSMETICS AND DENTIFRICE chemistry offer a fertile field for radioisotope applications. With diversified interests in soaps, detergents, and cosmetics, many problems arise for which radiotracer techniques are ideal. Many of them are difficult or impossible to solve by normal analytical methods. The three typical studies presented here are concerned with how a chemical used as an inhibitor of tooth decay is adsorbed in the oral tract, adsorption of fluorides on teeth, and retention of cosmetic ingredients by skin.

IN-VIVO ADSORPTION

Considerable investigation has been made concerning use of the N-lauroyl sarcosines as inhibitors of tooth decay (*1*). Since these compounds are adsorbed on proteins, quantitative *in-vivo* studies of this adsorption are desirable (*2, 3*). Routine analytical methods for these substituted sarcosines are not sufficiently developed. In contrast, the high sensitivity of radiotracer techniques provides a solution. *In-vivo* studies in white rats have been made to determine the metabolic fate of the tagged compounds and the length and amount of retentiveness in the oral tract.

How Much Activity?

For uneven distribution of tracer on tissue, the quantity of activity required to assay can be as low as 1% of the administered activity per gram of tissue. For even distribution, an activity of about 5×10^4 dpm/gm of tissue is needed to assay. Six to 8 μc of tagged agent in the presence of stable compound are administered to each rat as aqueous solutions and dentifrice formulations. This activity level corresponds to a total dose of about 10^7 dpm for a 200-gm rat.

Counting

After selected exposure times, the rats are sacrificed and autopsied. Selected organs are combusted at 850–1,000° C in the presence of oxygen, and the radiocarbon is assayed in the form of carbonate. An amount of tagged compounds identical to the administered dose is combusted and converted to carbonate for a control. Only relative counting is desired, so Q-gas* is used in the G-M region, rather than proportional counting.

*98.7% helium, 1.3% butane.

A further consideration is that 100 analyses for each set of 5 rats are involved. Liquid scintillation counting would be tedious. End-window counting is avoided because of the hygroscopic nature of the carbonate, and the known possibility of exchange of the tagged carbon dioxide with stable carbon dioxide in the atmosphere.

Over-all precision of the method is good. In general, in the tissues of different rats where about one third of the activity is located precision is ± 10–12% for a counting time of five 3-min periods. In tissues where approximately 1% of the activity is found, precision is about $\pm 20\%$. Accuracy of the technique is not known since no method has been developed to date for the quantitative measure of these substituted sarcosines *in vivo*. However in the metabolic studies the amount of radioactivity in the various organs, feces, and urine was totalized and $100 \pm 5\%$ of the radioactivity was accounted for.

FLUORIDE PROBLEMS

Dentistry's increasing use of fluorides stimulates interest in using these salts in dentifrices. Studies of dentifrice formulations determine conditions and ingredients necessary for optimum adsorption and retention on teeth.

Incorporation of sodium fluoride or stannous fluoride in dentifrice stimulates interest in fluoride and tin analyses. Adsorption of fluorine onto extracted human teeth is of prime interest since adherence to this substrate is desired. Studies with powdered dental enamel, which is more readily available than extracted teeth, furnish preliminary and supplementary data.

Since normal analytical methods have not been sufficiently developed, we were interested in using F^{18} as a tagging agent for fluoride studies. It was thought that tagging the cation would be desirable, as the action of cation and anion in adsorption studies and *in-vitro* reactions would not be the same. This was later found to be true.

We Choose C^{14}

The N-acyl sarcosine molecules contain oxygen, nitrogen, carbon, and hydrogen. Since oxygen and nitrogen have no satisfactory isotopes, the label must be C^{14} or tritium. Tritium is not used because of its weak beta (0.015 Mev) and the possible exchange of the tagged atom in the molecule with stable hydrogen. Hence, C^{14} is used as tagging agent and sodium N-lauroyl sarcosine-1-C^{14}, sodium N-palmytoyl sarcosine-1-C^{14}, and sodium N-lauroyl sarcosine-2-C^{14} are synthesized (5).

FLOW-GAS CELL especially developed for assays of materials retained on the skin of live rabbits. This solved problems posed by contamination and breakage with end-window tubes

Labeling with F^{18}

At the time of the initiation of the fluoride studies, F^{18} was not available commercially. A sample of lithium hydroxide was bombarded with alpha particles, and the resultant lithium fluoride was converted to the sodium salt by ion exchange with sodium phosphate. Subsequent development of a procedure for reactor production of F^{18} in larger quantities made it possible to run a series of studies using this tagging agent (4).

With both the sodium and stannous salts of F^{18} we studied adsorption on powdered human dental enamel using 1 μc/100 mg of substrate. We also made similar studies on extracted human teeth using $\gtrsim 20$ μc per tooth. These levels of activity were established after taking several factors into consideration. Duration of the experiments was at least 4 hr or two half-lives of the isotope. The original specific activity of F^{18} was considered to be 1 mc/mg. In addition, the amount of adsorption of radioactive fluoride occurring on the substrate determines the activity of the sample used. In the case of powdered dental enamel with the ratios of stable to radioactive fluorine used, an uptake of as low as 0.05% can be followed over a period of several hours.

In experiments with extracted human teeth where the total adsorbing surface is low, experimentation shows that adsorption down to 0.02% can be followed for periods up to 6–7 hr if at least 20 μc of F^{18} is used per tooth. However, it is important to remember that accuracy is decreased considerably after 6 hr because of radioactive decay. Furthermore, the type of instrumentation used has a direct bearing on quantities of tracer used—this aspect was fully investigated.

In all evaluations, decay corrections are eliminated by using a diluted control sample of F^{18} placed in a second thin-mica-end-window detector attached to a second scaler. This control is counted at the same time as each experimental sample. In general, it is found that 2.5% precision can be obtained providing sufficient quantities of F^{18} are used and the studies are not extended more than 10 hours.

Tin Tagging

Dental fluorides also are studied by tagging the tin cation. Two isotopes of tin are available as tagging agents—Sn^{113} and Sn^{121}. The former undergoes K capture and has a half-life of 112 days, whereas Sn^{121} emits 0.4-Mev beta particles with 27 hr half-life. Sn^{113} is used primarily because of its longer half-life. The 24 kev x-rays from K capture can be counted from dry samples with good efficiency in a flow-gas chamber using a Q-gas mixture of 99.05% helium and 0.95% isobutane.

Sn^{113} chloride of specific activity 3.8 μc/mg was received and converted to the fluoride by reaction with 48% hydrofluoric acid, the resultant hydrogen chloride being removed by distillation. Adsorption experiments were run with several dentifrice formulations, and the amount of pickup from centrifuged slurries was determined on powdered dental enamel as well as on extracted human teeth.

Since the Sn^{113} decays with formation of In^{113}, a 0.354 Mev gamma emitter of 17-hr half-life, all samples to be counted are allowed to stand for 48 hr before radioassay is undertaken. This allows transient equilibrium to be reestablished between the Sn^{113} and In^{113},

and validates the radioassay for tin.

Self-absorption curves are run on all ingredients present at the time of assay, and a small correction factor is necessary with the enamel. Also, the humectants present, especially glycerin, absorb the K-capture x-rays to a marked degree. However, since all adsorbing substrates are thoroughly rinsed with water in experiments, little or no humectant is present on the dental enamel or teeth at the time of assay. But correction values of humectants are necessary in determining the amount of tin initially present in the centrifuged slurries of the dental cream. Precision is ±2%.

SKIN RETENTION STUDIES

For the most part, usual methods of analysis are totally inadequate in one field of cosmetic chemistry—assay on the living animal. Attempts to extrapolate "test-tube" or *in-vitro* results to what will occur in the presence of living tissue generally has resulted in failure. Often valuable information can be obtained by conducting the studies *in vivo* using radiotracers.

Interest is quite high in cosmetic chemistry in the determination of length of retentiveness or adsorption of various agents on living tissue. Two *in-vivo* adsorption studies illustrate the use of radiotracer techniques in this field.

The relative adsorption of two organic compounds on living animal skin is wanted. The first experiment determines the relative pickup and retention of a bacteriostatic agent from soap formulations by the skin of white rabbits. The second experiment measures relative retention of an emollient from a lotion formulation by human and animal skin under various conditions. In both instances C^{14} is used as the tagging agent and radiocarbon is incorporated into the molecules by chemical synthesis.

Counting on Skin

Preliminary investigation into the method of radioassay was undertaken using conventional thin-mica-end-window tubes such as the Tracerlab TGC-2 or Nuclear-Chicago D-34. Several defects became apparent in this manner of detection. First, sensitivity is very low with weak beta emitters such as C^{14}. This is due not only to the attenuation of the particles by the window but also to the lack of intimate contact between window and surface area counted. If the window is brought into intimate contact with the adsorbing substrate, the tube is contaminated or the window breaks very readily, especially with movement of the surface as in the case of a live animal. Secondly, to correlate a series of results, it is necessary to maintain a constant distance between the G-M tube and the surface. A spacing device used to hold the G-M tube and maintain constant distance is only partially effective.

The figure shows a special flow-gas cell devised at these laboratories for *in-vivo* assay. By use of a cell made of 1½ in. dia. brass tubing with an anode of No. 32 copper wire, and by excluding air with a rubber gasket and using Q-gas composed of 99.05% helium and 0.95% isobutane, a counting device was made that possesses an operating voltage of 1,300 volts and has an operating plateau of at least 600 volts with a slope of 2%/100 volts. The cell is 10–12 times as sensitive to C^{14} beta emissions as is an end-window tube held within the safest minimum distance from the shaved skin of a white rabbit. With higher-energy beta emitters such as P^{32} and Ra D, sensitivity is only 2–4 times that of an end-window tube.

The flow-gas cell is being used in both studies—experiments with the tagged bacteriostat on the skins of live rabbits and studies of the tagged emollient on human skin. Both studies are in progress and precision appears to be better than ±7% when samples containing $<0.05\mu c/cm^2$ are counted for 5 min. No other methods of assay are known for these studies.

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F^{18}-Positron Counting

Although annihilation of F^{18} positrons occurs with resultant 0.51-Mev gamma rays, the photon formation is not sufficient for measurement by such "high-efficiency" G-M tubes as the Tracerlab TGC-8 and TGC-20 or with an Atomic scintillation spectrometer. Direct counting of 0.65-Mev positrons was undertaken with thin-mica-end-window G-M tubes such as the Tracerlab TGC-2.

Relative values can be obtained readily in adsorption studies; that is, that dentifrice formula A is better than dentifrice formula B for the deposition of fluoride on a selected medium. However, to obtain quantitative values (micrograms of fluoride deposited per milligram of substrate) self-absorption curves must be determined for all components in the dentifrice at the time of assay as well as for the adsorbing substrate.

Safety with C^{14} . . .

Rigid health and safety rules normally followed are observed with C^{14}. Although no external radiation hazards exist, care is taken to prevent accidental ingestion of radioactivity. Rubber gloves are worn when handling radioactive samples during synthesis of compounds or when handling radioactive tissues. Sample pipetting is undertaken only with remote devices. All samples are contained in porcelain trays to prevent contamination due to spills.

. . . with F^{18}

Since F^{18} emits positrons, annihilation gamma rays arise posing health and safety problems not normally encountered with beta emitters. The samples received from Brookhaven generally possess enough activity to deliver 200–500 mr/hr at the container surface. Therefore, preliminary unpacking, opening of the can and plastic bottle, and dilution of the sample to the desired volume are undertaken behind conventional lead wall of 2-in. contour bricks. Constant monitoring of personnel involved in the unpacking is undertaken using a Tracerlab SU-1F "Cutie Pie" and/or a Victoreen Model 592 gamma survey meter. During actual experiments the personnel exposure rate is low. Nevertheless, everyone in the laboratory wears a pocket ionization chamber in addition to the usual film badge.

Activation Analysis—What Can It Do for You?

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MOST OF THE TOPICS under consideration in this special report on applying radiation in industry emphasize the analysis of a process by means of a measurement of the radioactivity of a radioisotope introduced as a tracer early in the experiment. However, activation analysis is different in that a sample to be analyzed is subjected to an "activation" by means of a source of nuclear particles to form artificial radioisotopes of the element being analyzed. The radioactivities are then measured to determine the concentration of the element in the sample.

History. Activation analysis was conceived shortly after the discovery of artificial radioactivity in 1933 and has progressed from this beginning to its present use as an analytical method of analysis. Although applications of charged-particle activation analysis have been reported (*1, 2*), neutron-activation analysis is most widely used (*3–5*). See Table 1.

Sources. Table 2 lists some of the neutron sources usable in activation analysis. Since the yield of neutrons from a reactor is much greater than from other types of neutron sources, it is the one most commonly employed.

Irradiation. The sample is irradiated in a reactor for an appropriate length of time. In this time, a measurable amount of one or more radioisotopes of the element to be determined is produced. The rate of growth of the number of radioactive atoms in the stable isotope of the element being determined is proportional to the number of atoms of the target nuclide in the sample, the flux of neutrons irradiating the sample, the activation cross section for the nuclear reaction, the half-life of the radionuclide produced, and the duration of irradiation.

Counting. Once the irradiation has been stopped and production of the radioisotope of interest has ceased, it is necessary to assay the radioactivity induced in the sample. Sometimes a direct measurement of the radioactivity in the sample can be made by placing the irradiated sample into a counter and determining the half-life and analyzing the energy of the radiations emitted. Most often, a chemical separation is necessary.

The usual method is one in which a known weight of the element of interest is added to a solution of the irradiated sample as a "carrier" for the radioactivity. The chemical separations may involve techniques such as a precipitation, ion exchange, electrodeposition, solvent extraction, or distillation. After the experiment has been carried through the separation stages, the yield of the carrier element is determined in some manner, and the carrier and the radioactivity are then put into a suitable mount for counting the radioactivity. The radiochemical purity of the separated radioelement can be determined either by decay or absorption studies or by a gamma-spectral analysis (*6*).

Standardization. In practice, a standard containing a known amount of the element to be analyzed is irradiated and processed in the same manner as the unknown sample. Thus, by comparing the radioactivity of the desired radionuclide in each sample, it is possible to determine the concentration of the element of interest.

Advantages. Activation analysis is a sensitive method of analysis for most

TABLE 1—Sensitivity

Element	*Limit of measurement* (μg)*	*Element*	*Limit of measurement* (μg)*
Al	0.1	Ni	2.0
Sb	0.004	Nb	10.0
As	0.002	Os	0.03
Ba	0.05	Pd	0.005
Bi	5.0	P	0.02
Br	0.003	Pt	0.05
Cd	0.05	K	0.08
Ca	5.0	Pr	0.002
Ce	0.1	Re	0.007
Cs	0.03	Rh	0.01
Cl	0.03	Rb	0.03
Cr	0.2	Ru	0.1
Co	0.02	Sm	0.0006
Cu	0.007	Sc	0.002
Dy	0.00003	Se	0.05
Er	0.02	Si	1.0
Eu	0.00003	Ag	0.1
F	~2.0	Na	0.007
Gd	0.01	Sr	0.6
Ga	0.007	S	5.0
Ge	0.4	Ta	0.007
Au	0.003	Te	0.1
Hf	0.02	Tb	0.002
Ho	0.0004	Tl	0.6
In	0.0001	Th	0.05
I	0.002	Tm	0.002
Ir	0.0004	Sn	0.2
Fe	1.0	Ti	10.0
La	0.002	W	0.003
Lu	0.0003	U	0.01
Mg	2.0	V	0.01
Mn	0.0006	Yb	0.002
Hg	0.1	Y	0.01
Mo	0.1	Zn	0.07
Nd	0.1	Zr	0.7

* That weight of the element that will produce 40 dps activation in a neutron flux of 5×10^{11} n/cm²/sec for four weeks or until saturation if that is sooner.

elements. Microgram quantities are readily detected. For example, the activation analysis service program at the Oak Ridge National Laboratory (7) has been used to determine microgram and submicrogram quantities of at least seventy elements in many different materials. Table 1 lists some of these elements.

The ultimate limits of sensitivity have not been established; irradiations in higher neutron fluxes will extend these limits downward. More refined methods of counting also will increase the sensitivity.

Activation analysis is favored by its specificity—purity of the radioactivity induced into the stable isotope(s) of an element can be checked by half-life and energy measurements. Also, interference from the element being analyzed for is minimized unless the element has been introduced into the sample before the start of the irradiation.

Limitations. Activation analysis, like all other methods of analysis, has certain limitations. For instance, physical limitations can occur in the size of the container or facility available for irradiation. Another limitation can be described as a chemical limitation. In this, those processes involving structural damage and decomposition of the sample material, the radiochemical purity of the separated radioelement, and processing the sample material to insure that it is in the same chemical form as the "carrier" must be considered.

Other limitations are concerned with nuclear effects, such as self-shielding, formation of the radioelement being analyzed for by other neutron reactions, and formation of interfering radioactivities. Most of these limitations can be taken care of during the analysis.

Future. Activation analysis can be applied to many diverse materials. It has certainly provided many interesting results not only as an independent method of analysis but as a comparative method. Also, it has provided information on ultrapure materials that could not be obtained by any other analytical method.

Activation analysis can become one of the most sensitive methods for determining elements in minute concentrations in a sample material. Thus, activation analysis has an important place in analytical chemistry.

TABLE 2—Neutron Sources

Neutron source	*Neutron flux* ($n/cm^2/sec$)
Reactor	10^{13}–10^{14}
Cyclotron	10^{8}–10^{9}
Van de Graaff	10^{6}–10^{8}
Ra-Be, 1 gm	10^{4}–10^{5}
Sb-Be, 1 c	10^{3}–10^{4}
Ra-Be, 25 mg	10^{2}

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CASE STUDIES

Activation Shows Trace-Metal Segregation

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ACTIVATION ANALYSIS was used to determine the distribution of microgram and submicrogram amounts of nickel in zirconium metal and its effect on the corrosion properties of zirconium metal. Only limited amounts were available for assay, prohibiting multiple conventional analyses.

A lower limit for the activation-analysis determination of nickel is 0.10 μg, based upon the detection and measurement of 40 dps of Ni^{65} beta radiations after a 5-hr irradiation in a neutron flux of 1.3×10^{13} n/cm²/sec. Reaction is Ni^{64} (n, γ) 2.65-hr Ni^{65}.

In a preliminary study a $\frac{1}{2}$-in.-long $\frac{1}{4}$-in.-diameter test ingot was rolled into a $5 \times \frac{1}{2} \times 0.01$-in. sheet weighing ~2 gm. The sheet was cut into 18 pieces 15×5 mm, each weighing 0.090–0.120 gm. Individual segments were weighed and wrapped in aluminum foil. The samples were activated for at least 5 hr in the Low Intensity Testing Reactor. After discharge from the reactor, each specimen was placed into solution and the radioactive nickel separated along with inactive nickel added as a carrier. The final precipitate was placed in a G-M counter and the beta radiation from the Ni^{65} measured. The radiochemical purity of the Ni^{65} was determined by a half-life measurement. In some instances, radiochemical purity was checked by an energy analysis of the gamma radiations emitted by the sample.

The results showed that the nickel was not uniformly distributed throughout the sample.

The same techniques were used to determine the distribution of nickel in zone-refined zirconium. The specimens available in these experiments usually weighed <0.20 gm, yet the few ppm of nickel could be determined within 3%. (For details see G. D. Kneip, J. O. Betterton, Jr., paper 90, 108th meeting of the Electrochemical Society, Pittsburgh, Pa., October 9–13, 1955.)

CASE STUDIES

Measuring Trace Elements by Activation Analysis

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TRACE ELEMENTS in aluminum (as impurities or intentionally added alloying constituents at concentrations less than a few ppm) are of great interest to metallurgists and electrochemists in the aluminum industry. Trace elements often seem to affect aluminum's corrosion resistance and metallurgical and mechanical properties.

The effects of large amounts of alloying elements have been explored in much detail. With some exceptions, the effects of trace elements are not well known because of the difficulty in determining the quantity of any one.

With the advent of radioactive tracers, techniques are available for quantitative analysis of many trace elements and for semiquantitative determination of their distribution in metallurgical structures. Significant among these techniques are activation analysis (discussed below) and microautoradiography (see box, p. 49).

Activation Analysis

Our activation analysis program developed in three distinct phases. First, several specific analyses were attempted. Very promising results were obtained, but it was found that the groundwork comprising the limitations and precautions that must be taken in activation analysis had not been laid satisfactorily. Then an investigation was made of the sources of error in activation analysis. These two phases of the program have been discussed previously (*1–3*) but will be reviewed here. Preliminary results on the third phase—activation-analytis methods for the qualitative detecsion of previously unknown impurities—also will be described.

Two of the specific analyses developed will now be described.

Sodium. Spectrographic analysis for sodium was believed subject to error because of difficulty in preparing and calibrating standards. Neutron-activation analysis appeared to have sufficient sensitivity and inherent accuracy to be applied as an independent method of analysis. The $Al^{27}(n,\alpha)Na^{24}$ reaction limits the accuracy of the activation analysis, but, by proper choice of irradiation conditions, this reaction is reduced to make a contribution of 0.0001% sodium equivalent.

A double zinc-uranyl-acetate precipitation procedure gave radiochemically pure separation under all conditions studied. The observed precision for several duplicate analyses was ±1%, and the limiting accuracy of the determination was ±0.0001% because of the transmutation reaction with Al. The results compare favorably with sodium concentrations determined by the procedures applied to spectrographic standards.

Phosphorus. No complicating reactions are encountered in an activation-analysis procedure for determining trace concentrations of phosphorus in Al and Al_2O_3 (*2*). Irradiations are performed under the thermal-neutron conditions used for sodium analysis. Radioactive tungsten is the only interfering radioisotope in the chemical procedure, which consists of adding carrier phosphorus, oxidizing to phosphate, and a double precipitation as phosphomolybdate. Phosphorus contents in the range 0.001–0.0001% are determined within 5% of the absolute value. A sensitivity of 0.0000005% phosphorus is believed possible.

Errors in Analysis

Errors in activation analysis (*3, 4*) can be encountered during irradiation, chemical separation, and counting measurements.

Gross errors result from attenuation of the neutron flux. Attenuation of flux by the sample package can result in errors as great as 16%. A larger, and more difficult to evaluate, error can be introduced by attenuation of the neutron flux by the samples themselves. During the irradiation of antimony, errors as great as 30% can be induced. It is noteworthy that this error can be encountered and go undetected if samples larger than about 10 mg are irradiated. Accurate and precise determinations by activation analysis cannot be made unless independent study shows that factors causing flux variations are absent.

Detecting Trace Elements

If a quantity of an aluminum alloy is irradiated, a large variety of radioactive isotopes are produced. Generally, one or two isotopes are produced in such quantity that the presence of other radioactive isotopes is masked by their radiations. Chemical separation of the isotopes produced makes it possible to detect and identify a large number of trace-element impurities in a sample. Copper, gallium, and the rare earths at concentrations of less than 1 ppm in Al have been detected by such a technique (*5*).

The qualitative identification of several trace elements might be accomplished by characterizing the radiations with a gamma-ray spectrometer. Unfortunately, the resolution of gamma-

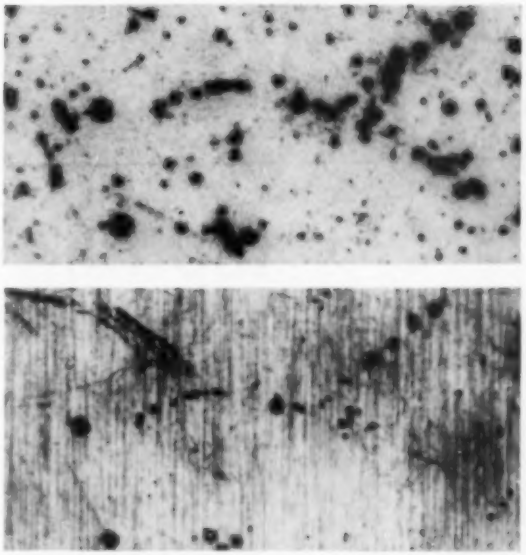
Autoradiography—A Second Tool

The radioactive isotope has provided a second technique of great value in studying trace elements. Not only can the quantity of a trace element be measured, but its distribution on a surface can be determined semiquantitatively by autoradiography.

For example, new information about the mechanism by which mercury accelerates the corrosion of aluminum has been obtained from autoradiographic studies of the Hg distribution on a pitted aluminum surface as shown in the figures at the right. The autoradiogram (top) and the photomicrograph (bottom) are both 20 ×. There is mercury in every corrosion pit but there are many points where pits have not developed where there are mercury deposits of about the same size. This distribution could not have been measured by any existing technique other than autoradiography. The quantities of mercury responsible for the blackening on the autoradiogram are of the order of 1μg or less.

Here's another example. In connection with a recently developed radioactive tracer technique for measuring the specific surface area of metallic aluminum surfaces (NU, Nov. '55, p. 22) autoradiographic techniques were used to determine the uniformity of the distribution of as little as 0.23 μg/cm² of PO_4 on metal surfaces. Autoradiographic techniques defined distributions that could not have been obtained directly by any other measurement technique.

In the autoradiography of thin metallographic sections new techniques have made it possible to produce sections as thin as 3μ. A useful resolution as low as 8μ can be obtained with these sections clamped to a photographic emulsion (8).



Autoradiogram (20X) of mercury and photomicrograph (20X) of corresponding portion of pitted surface of 3003 Al sheet exposed to 1,000 ppm mercury solution

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ray spectrometers is not sufficient to permit characterizing more than a very few gamma energies simultaneously, and these only when emitted in nearly equal quantities.

Recently we attempted to determine what elements were present in a quantity of superpurity zone-refined Al. This material contained less than 0.00005% copper, less than 0.0002% iron and less than 0.0001% magnesium and undetected amounts of 17 other elements frequently found in Al. The principal isotope produced upon irradiation with neutrons was characterized by decay and beta-energy measurements made directly on the sample. Observed half-life was 63 days and beta energy was between 0.3–0.45 Mev. By comparing the half-life with those given in tables (*6*) and by examining the decay scheme of the possible isotopes (*7*), it was determined that the principal activity was probably Zr^{95}.

The sample was dissolved and carrier zirconium was added and precipitated as zirconium pyrophosphate. The presence of zirconium in the superpurity aluminum was confirmed by counting measurements on the zirconium precipitate. A rough estimate of 0.0005% zirconium was made from sample size, neutron flux, irradiation conditions and detection efficiency. The presence of zirconium had been neither suspected or anticipated.

To determine other impurities present but masked by the Zr^{95}, a quantity of the Al was irradiated and carried through a chemical fractionation similar to that used in the classical hydrogen-sulfide qualitative-analysis scheme. Fractions were separated representing the insolubles, the acid-sulfide group, the alkaline-sulfide group (further fractionated according to the amphoteric character of the hydroxides) and the alkaline-earth group. Carriers such as silicon, iron, and copper were added for each group and subgroup.

Decay rates and radiation energies from each group were measured and isotopes identified wherever possible. Molybdenum, copper, iron and gallium activities were identified with reasonable certainty. All of these elements were estimated to be below the spectroscopic limit of detection.

It would seem that a very useful technique for the qualitative detection and semiquantitative estimation of a rather large number of trace-level impurities in a given sample could be developed. This technique, which could be termed "qualitative analysis for trace elements," could be of great value. The major obstacle is that of determining carrier chemistry techniques that will give unique and complete separation of trace quantities of material from a given matrix.

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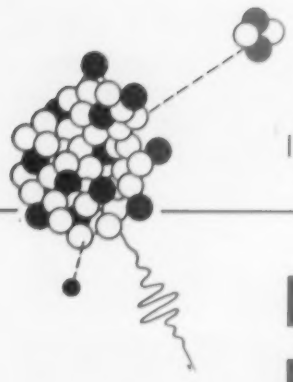

Isotopes Solve Mixing Problems

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RADIOISOTOPE TECHNIQUES for determining industrial mixing can be applied in all kinds of process industries. Blending of gasolines, lubricating oils, greases, waxes, paints, and cements are large-scale industrial operations that can be followed with radiotracers. Uniform mixing is important in the manufacture of alloys, plastics, paper, cosmetics, and detergents. Easy to imagine are possible applications in processing fortified foods and in the dairy, bread, and cereal industries.

There is an optimum time for every blending operation. Too little gives a nonuniform product; too much is uneconomical and slows production. Tracer tests on any operation will determine this optimum time and result in worthwhile economies in many large manufacturing industries. High dilution or use of short-lived tracers avoids appreciable radioactivity in products reaching the consumer.

Grease mixing has been studied with I^{132} (*1*). Use of this 2.5-hr isotope, obtained by milking from its longer-lived parent, Te^{132}, assures disappearance of the radioactivity before the product leaves the plant.

Heterogeneous reactions require good mixing for efficient production. Scrubbing of impurities out of products, acid or alkaline treatment of petroleum stocks, and catalytic hydrogenation, cracking, and isomerization are large-scale operations in which information about mixing is of value. Catalyst loss in cracking units is an example (*2*, *3*).

In most cases, fundamental principles of mixing can be studied much easier with radiotracers than with other techniques. Mixing between adjacent liquids during passage through a pipeline lends itself to theoretical analysis (*4*). Experiments on this subject can be readily extended to study the effects on mixing rates of liquid velocity, pipe size, viscosity, and density.

The severely practical problems of producing iron and steel have furnished the incentive for starting fundamental research on the hydrodynamic properties of molten metals (*5*).

Problems solved include . . .

Method	*Results*
. . . Homogeneity in grease mixing	
I^{132} is added to ingredients of a batch to be mixed. Radioactivity is measured continuously at a fixed point during mixing. When uniform activity is reached, mixing is complete.	In testing many routine operations it has been found that some were being carried further than necessary, and others were not going far enough.
. . . Catalyst losses in a fluidized cracking unit	
Fresh catalyst is labeled with Co^{60} and added to the circulating inventory in a plant. Samples are withdrawn from the plant and assayed.	There is rapid approach to uniformity; mixing is essentially complete within 1 hr. Small decrease in specific activity over next 24 hr shows dormant portion of catalyst that interchanges only slowly with main circulating charge.
. . . Mixing between adjacent liquids in a pipeline	
An oil-soluble compound of Ba^{140} is used as the tracer.	Mixing coefficients of 1–2 ft^2/sec are found for crude petroleum.
. . . Mixing of alloying elements in molten iron	
Radio-Co, -Cr, -W, -S, -P added to liquid metals measure the rates of spreading and complete-mixing times.	Mixing coefficients are 0.1–0.5 ft^2/sec—which are not very different from those found for petroleum.

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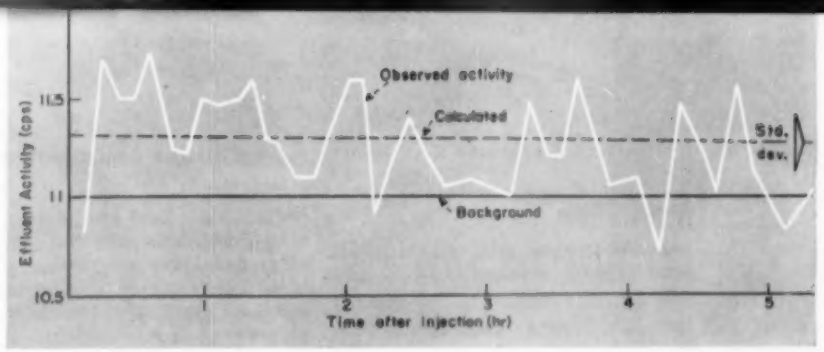

FIG. 1. Mixing in a 50,000-gallon surge tank. Fluctuation of observed counting rate about calculated ideal curve indicates extent of mixing

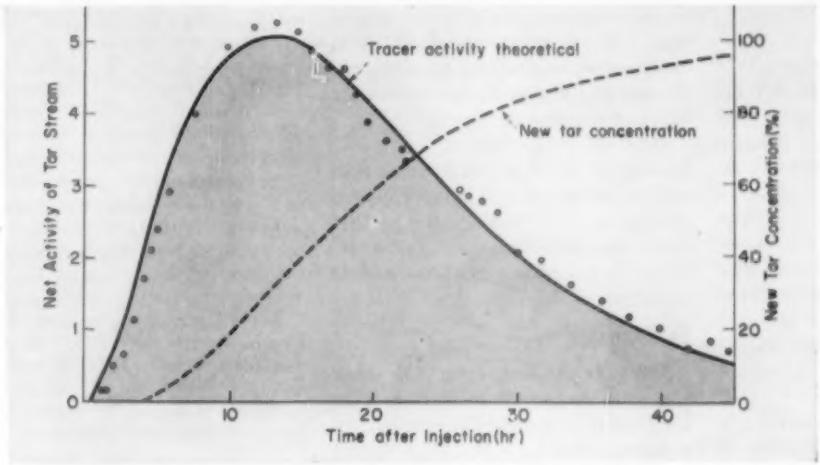

FIG. 2. Mixing rate in crude stills is great, as shown by early rise of tracer curve

CASE STUDIES

Mixing in Surge Tanks and Stills

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RADIOISOTOPES can be applied to the study of mixing problems. Quantitative measurements are possible with two parameters proposed by Danckwerts—scale of segregation and degree of segregation (*1*). This is shown by two examples—mixing in a 50,000-gal surge tank and segregation of stock in crude stills.

SURGE-TANK MIXING

The feed to a thermal cracking plant consists of two main streams, one of varying high viscosity and one of fixed low viscosity. The rates of these streams are adjusted automatically; the aim is to maintain constant viscosity of the combined stream. The combined stream is routed through a 50,000-barrel surge tank. To further reduce variations in viscosity of the stream, mixing is provided in the surge tank by circulation through a loop at 100,000 bbl/day.

In spite of these measures, the effluent from the surge tank to the thermal cracker suffered abrupt and severe changes in viscosity. Since control of thermal cracking units depends on viscosity, the effectiveness of mixing in the surge tank was questioned, and radiotracers were called upon to provide the answer.

The phase tracer in this case can be any oil-soluble tracer with a hard gamma. Zr^{95} was available as a chelate compound with thenoyltrifluoroacetone. Its 0.73-Mev gamma made it suitable for measurement through

the steel walls enclosing the stock to be traced.

This line of attack was proposed: (a) tracer would be injected into one of the lines feeding the surge tank; (b) the outlet line to the cracking plant would be monitored to measure the radioactivity in the mixed stock—a steady level would show good mixing; variations would be a measure of incomplete mixing.

How Much Tracer?

The amount of tracer needed depends on detector sensitivity. G-M tubes with 1 × 12-in. active volumes were available; the more sensitive scintillation counter was not, although it would have been preferred. The counting sensitivity of a 1 × 12 in. G-M tube on a 10-in. insulated pipe was estimated from earlier measurements with this isotope to be 85 cps at a concentration of 1 mc/bbl. Use of four tubes in parallel would increase sensitivity to 340 cps.

The minimum counting rate recognizable above background depends on the time constant of the counting ratemeter or on the interval chosen for recording scaler readings. From studies of mixing in pipelines it was estimated that a spot injection into the feed line would be spread over ten barrels by the time it reached the tank (*2*). At a flow rate of 0.5 bbl/sec, a 20-sec interval was the highest resolution we could use to study the scale of segregation. At a background of 2.5 cps/tube, a bank of four tubes would deliver 200 ± 14 background counts in 20 sec. Thus 28 counts over background (two times standard deviation) in 20 sec would be identifiable at 95% certainty. To label the 40,000 bbl of stock resident in the surge tank to this level would require (1.4 cps × 40,000 bbl)/(340 cps/mc/bbl) = 160 mc.

Only 50 mc of tracer was available for the test. Could any of the specifications be relaxed to justify going ahead, or would it be necessary to wait for a new supply of zirconium? To observe 0.5 cps increment over a background of 10 cps with 95% certainty would require $(10/0.25)^2 = 1{,}600$ counts or about 160 sec—corresponding to 80 barrels. Since there was no assurance that the estimated minimum mixed volume (10 bbl) would be realized in the test, we decided that a 50-mc injection probably would give useful results. We would take note of the times at 1,000-count intervals on the scaler.

Is There a Hazard?

At the counting rates anticipated, it is evident that the plant operators would not be exposed to any external radiation hazard from the process pipes. In the cracking process, the stock passes through long narrow hot tubes. Because it might be concentrated in a relatively small volume in this process, we arranged to survey the furnace and the coke reamed from the tubes at the next shutdown.

Laboratory distillation of stocks containing the thenoyltrifluoroacetone complex of Zr^{95} showed that it was completely retained in the coke so that there was no chance of finding activity in the refined products sold to consumers.

Making the Test

To make the test, four G-M tubes were fastened to the outlet line from the tank and connected in parallel into a scaler. Every 1,000 counts tripped the register, and the reading of an electric timer was noted at each 1,000. First, some 20,000 background counts were recorded giving a rate of 11.0 cps. Then, the tracer solution was injected from an inverted "Sparklet" bottle* through a special cap into the inlet line. The injection was spread out over 1.8 min; it was carried into the tank in about 50 barrels of stock. About 11 minutes later the tracer appeared at the observing station, giving a net count of about 0.6 cps. The flow of the tracer out of the tank was observed for 5.5 hr, during which the counting rate fluctuated as shown in Fig. 1.

Results

The magnitude of the peak counting rate showed that the labeled stock had undergone very extensive mixing in the tank, for the counting rate of the 50 barrels entering the tank was calculated to be (340 cps/mc/bbl)(46 mc/50 bbl) = 310 cps. The observed peak rate of 0.6 cps meant that the original stock had been diluted not less than 500-fold before leaving the tank.

But the fluctuations in counting rate showed that mixing was far from complete. The broken line in Fig. 1 is the calculated counting rate that would have been observed if mixing were rapid and complete. The deviations from this line are much greater than the statistical errors of counting, the magnitude of which is indicated.

The two parameters of mixing can be inferred directly from the plot of counting rate vs time. The intensity of segregation, measured by net counting rate, varied from zero to twice the value for complete mixing. The scale of segregation measured along the time axis is of the order of 20 min, equivalent to a volume of about 500 bbl. Values of these parameters could be determined more precisely by improving the resolution of the test. This could be done by using more tracer, or, preferably, by substituting scintillation counters for the G-M counters.

In Retrospect

This test showed that there was considerable mixing in the tank, but complete mixing was not attained. In this intermediate range the results were difficult to interpret in terms of variation of viscosity of thermal cracker feed resulting from poor mixing in the surge tank. In another such test we would prefer to inject the same quantity of tracer uniformly over a period comparable with the residence time in the tank—6–30 hr in this case. This would give results directly interpretable

* Ordinarily sold for preparing carbonated beverages.

Advantages of Radiotracers

1. Specific isotopic tracers usually are not needed. Any labeled compound that is compatible with the component to be traced will serve. Thus, instead of an isotopic tracer, a phase tracer is sufficient. With the wide latitude of properties thus permissible, it is nearly always possible to select, from the variety of radioisotopes available, a suitable compound for a given mixture.
2. Ease of measurement by the radioactive method gives it unparalleled convenience. It usually is not necessary even to take samples. In fact, more information is obtained by continuous observation of the counting rate of a detector exposed to an effluent stream or placed inside the mixing vessel.
3. The sensitivity of radiotracer measurements at high dilution extends the usefulness of the method to the largest volumes handled in industrial plants.
4. Both mixing parameters proposed by Danckwerts are related directly to quantities measured in a radiotracer test (*1*).

in terms of viscosity of the effluent stream.

The radiation survey of furnace tubes during the next shutdown showed that no hazardous accumulation of the tracer had occurred. Some portions of the coke showed a count slightly above background, but nothing approaching tolerance levels.

SEGREGATION IN STILLS

An unusual batch of crude oil was to be refined, starting as usual with the continuous distillation process in a battery of crude stills. Because of the characteristics of the tar from this crude, the refinery operators wanted to segregate it as completely as possible from the tar ordinarily produced. They expected the still's baffle plates to prevent extensive mixing.

If a suitable radiotracer were added to the feed at the moment of switching from the regular to the special crude, the tracer peak in the tar issuing from the still bottoms would mark the logical moment for switching the tar to a separate tank. The spread of tracer would show extent of segregation.

An added qualification for the phase tracer in this test was that it be nonvolatile. Co^{60} naphthenate was chosen because laboratory tests had shown it to be nonvolatile, and it would follow tar through the stills. Also its solubility and stability in hot oil streams had been proven in earlier refinery tests. The quantity required would depend on degree of mixing assumed. Throughput rates and capacities pointed to an expected breakthrough about 20 hours after change-over. Making the pessimistic assumption that the tracer might be spread over a 20-hr period in the bottoms stream at a volume rate of 120 bbl/hr, a total volume of 2,400 bbl would be labeled. To double the background rate (10 cps for four tubes), with a counting efficiency (experimentally determined) for Co^{60} in a 6-in. bare pipe of 308 counts/second/mc/bbl, would require $(2{,}400 \times 10)/(308 \times 4) = 20$ mc. Ten mc was immediately available. This would be enough.

Safety

The tracer in this case would be left in the tar in minute amounts when it left the plant. Would measurable concentrations reach the consumer? Taking 20 mc in 2,400 bbl as a starting point, we calculated

$$\frac{20 \text{ mc} \times 1000\ \mu\text{c/mc}}{2400 \text{ bbl} \times 159{,}000 \text{ ml/bbl}} = 5 \times 10^{-5} \mu\text{c/ml}$$

This was already 35 times less than the allowable concentrations of Co^{60} in waste that might find its way into potable water. Since the dilution with more tar in the storage tank would further reduce the concentration, since this was to be a single test and not a continuing contamination, and since no one would drink tar anyway, safety requirements were amply satisfied.

Making the Test

A battery of four G-M tubes was fastened on the tar line from the last still and background was measured. The elapsed time in seconds was recorded at integral thousands of recorded counts, usually at intervals of 20–60 thousands. Cobalt naphthenate (9.5 mc) was injected into the new crude just as it was switched into the pump leading to the first still. About 2.5 hr after the change-over the first tracer appeared in the tar line with a recorded net count of 0.3 cps.

As shown in Fig. 2, tracer concentration gradually increased during the next 12 hr to a peak value of 5.2 cps above background. Then it went into a slow decline lasting over 42 hr. The tracer still showed 0.3 cps in the line when the observations were discontinued.

The operator was advised to switch the tar into a new tank as soon as the peak counting rate was reached. But it was evident that the hoped-for break between the two tars was reduced to a wide blur by mixing within the stills. The early rise and the shape of the tracer curve suggested that movement of tar within the still might result in something much closer to complete mixing than to the segregation desired and tacitly assumed.

Analysis

A mathematical analysis of the experiment was made assuming complete mixing in each still. The time constant for passage through a single unit under these conditions is the capacity divided by the throughput, and for consecutive stills the output is represented by an equation similar to that for consecutive reactions in chemical kinetics or radioactivity.

Operating data gave the time constants for these three consecutive stills as 0.107, 0.193, and 0.183 hr^{-1}, respectively. The general equation for the activity of tracer leaving the third still A_c at time t in relation to the initial concentration in the first still A_0 is

$$\frac{A_c}{A_0} = \frac{\beta\gamma e^{-\alpha t}}{(\beta-\alpha)(\gamma-\alpha)} + \frac{\beta\gamma e^{-\beta t}}{(\alpha-\beta)(\gamma-\beta)} + \frac{\beta\gamma e^{-\gamma t}}{(\alpha-\gamma)(\beta-\gamma)}$$

where α, β, and γ are the throughput rate constants for the three stills. From this equation and these constants we have calculated A_c/A_0 as a function of time. The function is plotted as the smooth curve in Fig. 2, multiplied by the value of A_0 in cps. The value of A_0 that would have been measured on the initial tar stream from the first still, 13.4 cps, was obtained from the total number of tracer counts observed during the test (450,000), multiplied by the rate constant α.

The excellent agreement between this calculated curve and the experimental points shows that the contents of each still are almost completely mixed. Only a small deviation from theoretically perfect mixing is suggested by the lag in the rising tracer curve (about 30 min) and the slightly higher peak. The baffles, supposed to prevent mixing, completely fail to do so.

On the assumption of good mixing, so well justified by the results of this test, it is possible to calculate the concentration of new tar in the bottoms line as a function of time. This has the form

$$C = 1 - \frac{\beta\gamma e^{-\alpha t}}{(\beta-\alpha)(\gamma-\alpha)} - \frac{\alpha\gamma e^{-\beta t}}{(\alpha-\beta)(\gamma-\beta)} - \frac{\alpha\beta e^{-\gamma t}}{(\alpha-\gamma)(\beta-\gamma)}$$

and is plotted as a dashed line in Fig. 2.

The result of this test suggests that there may be many industrial plants for continuous processing in which the theoretical throughput rates could be used to calculate residence times and reaction times if it were known that good mixing prevailed in the process vessels. The technique demonstrated here is a simple way to determine whether mixing is good enough to justify such calculations. A radiotracer test on any new or rebuilt plant would give definite information on which to base the plant operation.

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Industry Fights Wear With Isotopes

By M. EUGENE MERCHANT, HANS ERNST, and E. J. KRABACHER
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WHAT A REMARKABLE revolution has taken place in the entire field of wear testing in the past ten years—since the advent of reactor-produced radioisotopes! Our knowledge of wear has advanced remarkably. By virtue of the availability of these isotopes, gone are the days of the tedious, interminable, laborious conventional wear tests grinding out their meager data that, at best, could reveal only half the truth.

Today, thanks to tracers, the process of wear and all its practical ramifications are gradually becoming an open book. Already, in addition to the cutting-tool wear problem, such diverse wear problems as those of electrical contacts, automobile engines, plastic molds, wire-drawing dies, automobile tires, gears, and turbine wheels are yielding to isotope techniques. In each case, rapidity and ease of testing or new information about the process, or both, are resulting.

Plastic Molds

The problem of mold erosion in the molding of phenolic plastics is a problem that has plagued the plastics industry for as many years as phenolics have been molded. Yet who knew what effect mold pressures, preheat, resin modification, lubricants and fillers actually had on mold erosion? Only general facts could be obtained by conventional means, because of the prohibitively long times and large quantities of materials required to produce total wear of an accurately measurable amount. But, recently, radioactive tracers have been applied to the problem with excellent results (*1*).

By using a radioactive sprue bushing in a transfer-type mold and measuring the radioactivity of a part molded therein, accurate measurement of mold wear results. In ~30 minutes a complete mold-erosion test can be made, as opposed to ~3 weeks with any other method!

Engines

An important wear problem of economic and personal interest to most people is that of the "wear-out" of automobile engines. This is one of the first wear problems attacked by use of radioactive tracers. Even before the advent of reactor-produced isotopes, Ferris experimented with the possibility of measuring piston-ring wear by using cyclotron-produced radio-phosphorus (*2*). But he was not able to make the technique practical because of the problems of the short half-life of the phosphorus and the need for introducing this into the ring manufacturing process itself. However, in 1947, Pinotti conceived the idea of rendering the piston ring radioactive by exposing it to neutrons in a reactor (*3*). This resulted in a practical test method.

Tires

Automobile tires are coming in for scrutiny by radiotracers as they wear on starts, stops, curves and straightaways (*4*). This is done by incorporating radiophosphorus in the form of triphenylphosphate as a plasticizer in the tread rubber. By measuring the radioactivity of the road surface over which such a tire has passed, tread wear can be determined directly—and with a minute fraction of the time and expense involved in the usual interminable fleet-testing required conventionally.

Gears

Gears are one of the most widely used machine elements—covering the gamut from wristwatches to rock-crushers. They come in for their share of wear problems in practically all their applications, and the headaches caused by such wear are manifold. A good start towards a remedy consists of rendering one gear in a test rig radioactive, and by continuously monitoring the radioactivity of the oil circulating through that rig, the rate of gear wear is measured continuously and instantaneously (*5*).

Dies, Electrical Contacts

The tagged atom, finding its way into still other fields, has been applied to solving such quite different types of wear or erosion problems as those of dies and electrical contacts (*6, 7*). By using tracers it has been discovered that wire-drawing dies wear essentially discontinuously (rather than smoothly as a cutting tool wears). With automotive electrical contacts, tracers solve problems of pitting and metal transfer on such contacts as distributor points.

Turbine Cavitation

The effect of generator load on the rate of erosion of a turbine wheel by cavitation is determined directly and quickly by painting the wheel with an adherent paint containing a small amount of radioactive As^{76} then measuring, with a scintillation counter, the rate of change of the level of radiation at the outside of the machine (*8*).

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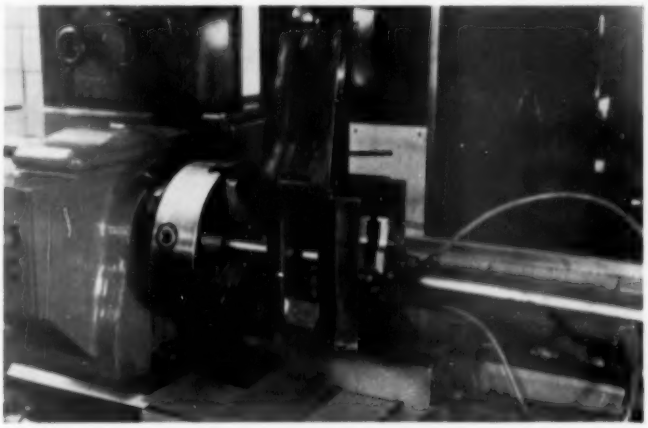

FIG. 1. Tool-tip holder (top right) used is remotely operable from end of long handle (top left) because tool tip is made radioactive so that its wear can be measured by counting radioactivity in chips. Any desired tool tip can be picked out of a storage turret and placed in cutting position on lathe. Nonroutine handling of radioactive tool tips is done with extension tweezers (bottom)

FIG. 2. Cutting chamber on lathe provides mount for tool holder and encloses cutting tool and cutting action so that radiation is shielded and the machine is protected from contamination

CASE STUDY

Tool-Wear Tests Speeded

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ANNUALLY, in the United States alone, over 15-million tons of metal are machined into chips, at a cost of over $10-billion. Obviously, proper machining practices play a very large part in the welfare of our national economy, as well as in world economy. Yet, unfortunately, even in recent years, much of the machining that is done to convert that huge quantity of metal into chips is carried out under far from economical conditions. While this is partly due to the use of obsolete machine tools, the second prime factor has been the difficulty and expense of obtaining detailed and accurate cutting-tool-wear or "machinability" information.

Wear Is a Problem

Cutting-tool wear is the major factor controlling machining costs. If tool wear is reduced, decreases result in both sources of machining costs: (a) labor and overhead on the machine tool, per part turned out, are lowered because more parts can be turned out per hour; (b) labor and overhead on cutting-tool resharpening, per part turned out, are lowered because less frequent sharpening is required.

The bottleneck in the process of obtaining good tool-wear or machinability information that can be applied in practice has lain in the extremely time-consuming and expensive conventional tool-wear testing methods. Conventional means to obtain a single reliable wear measurement under conditions duplicating shop practice require hours of time and hundreds of pounds of material. The reason is that over-all tool wear is so slight, even at failure, that total wear must be measured after a considerable time of cutting with conventional means of wear measurement.

Soon after the advent of pile-produced radioisotopes, it was realized that radioactive tracers hold the possibility of breaking the tool-wear-measurement bottleneck by permitting virtually instantaneous measurement of *rate* of tool wear.

Isotopes Offer Solution

In 1949 the decision was made to investigate the feasibility of developing a rapid tool-wear testing method using radioisotopes. In essence the method was to work with a radioactive cutting tool and to determine the rate of wear by measuring the radioactivity of wear particles resulting from a short period of cutting. Presumably these particles would be found mainly on chips that produced wear by their rubbing contact with the cutting tool, but also to a lesser extent, in the cutting fluid.

The first step in the feasibility study was to determine the level of activity required in the cutting tool and to make sure this level would not be so high as to make the test method cumbersome or impractical. The collected sample of wear products should have

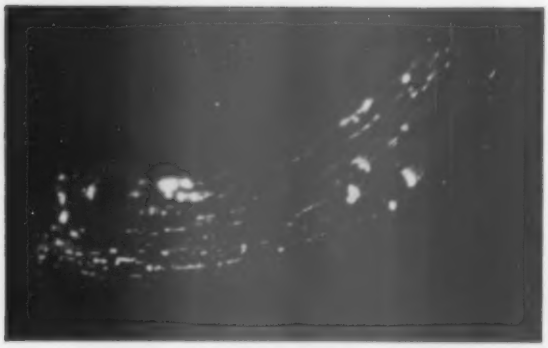

FIG. 3. Uniformity of wear process along the chips is illustrated by a typical autoradiograph of chip section (~0.2 × 0.9 in.). But over a period of a number of cuts a long-range undulation of wear usually takes place

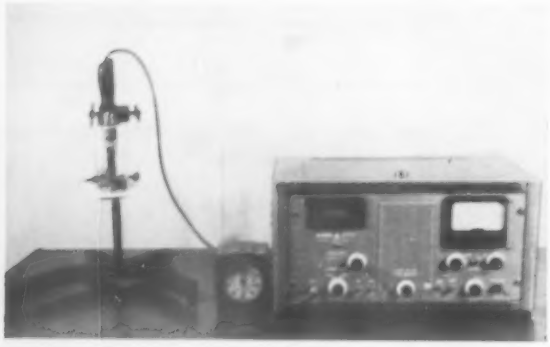

FIG. 4. G-M tube, scaler, and timer as used for measuring chip-sample radioactivity

an activity of ~50 dps or more so that this activity could be determined conveniently and rapidly with conventional counting equipment. It was known from measurements of total wear in conventional tool-wear tests that, in round numbers, an average of ~0.05 μgm/sec of tool-wear products result from cutting at feeds, speeds, and sizes of cut typically used in practice. This indicated that if a test cut of 6-sec duration was used, a specific activity of the tool material of only 5 mc/gm would be sufficient to get the necessary 50 dps ($0.05 \times 6 \times 10^{-6} \times 5 \times 3.7 \times 10^{7} = 55.5$ dps). Since the average cutting-tool tip need weigh only 2–3 gm, it was evident that the activity level of the cutting tool was well below that which can be handled safely and conveniently in routine experimental work with tracers.

Neutron Activation

The next question to be answered was how to obtain this level of activity in the cutting tool. Fortunately, practically all of the usual commercial cutting-tool materials contain several elements that provide radioisotopes of suitable half-life and radiation characteristics when subjected to neutron bombardment in a reactor. The important elements are cobalt, tungsten, tantalum, and, to a lesser degree, chromium. The characteristics of the effective isotopes of these elements are summarized in the table.

Calculation of the reactor irradiation time required to obtain the desired specific activity of 5 mc/gm from one or more of the above elements present in tool materials (in the usual percentages found in practice) showed this activity can be obtained in 20–60 days' irradiation at a thermal-neutron flux of 5×10^{11} neutrons/cm²/sec, such as is available in the Oak Ridge X-10 reactor (or in 2–6 days at a flux density 10 times this amount, such as is available in the Brookhaven reactor).

Since the above theoretical studies indicated no impediment to a practical method for using tracers to measure cutting-tool wear, a design study was initiated to develop apparatus with which to make turning tests. The aim was to provide maximum convenience and very ample health safety in handling the radioactive cutting tools. Radioactive materials with a level of activity of 10–20 mc, such as the cutting-tool tips to be used in this investigation, cannot be handled directly. Remote-handling equipment, together with some degree of beta- and gamma-ray shielding, is necessary.

To provide this and the desired convenience, the design study employed the principles of using the cutting-tool-tip holder as the main remote-handling manipulative device, and of using the required rigid mounting for the tool holder as the main shielding element.

Radioisotopes from Neutron Irradiation of Cutting Tools

Radioisotope	*Half-Life*	*Principal Radiation*
Co^{60}	5.3 yr	β^-, 0.31 Mev γ, 1.33, 1.17 Mev
W^{185}	73 d	β^-, 0.43 Mev (no γ)
Ta^{182}	115 d	β^-, 0.53 Mev γ, 1.2, 1.1 Mev
Cr^{51}	28 d	K capture (no β) γ, 0.32 Mev

Tool Manipulators

Figure 1 shows the remotely-operable tool-tip holder with which any desired tool tip can be picked out of a storage turret and placed in cutting position on the machine tool. During this operation, personnel need not come within 4 ft of the radioactive tip. Also shown are extension tweezers with which nonroutine manipulation of radioactive tips can be carried out. Figure 2 shows the tool-holder mount in position on the lathe. This mounting is actually a chamber in which the cutting operation can go on fully enclosed. It provides shielding and protection from contamination of the machine or surroundings by the chips or cutting fluid.

The possible problems of contamination and health safety that might occur from resharpening the tool by grinding were eliminated in this design by eliminating the need for resharpening. Each tool tip was provided with four cutting edges that could be used one at a time. Since a few seconds of cutting was indicated as sufficient to provide a wear measurement, many hundreds of cuts (wear measurements) could be expected with each tool tip before it becomes dull. On this basis, it was just as economical to discard the tip when dull as to attempt to regrind it. Thus, arrangements were made with Oak Ridge National Laboratory to send dull tool tips to them for disposal by burial.

Wear Tests

On the basis of the above design an application for radioisotope procure-

ment to obtain a service irradiation of a set of tool tips was filed on July 28, 1950 with the Isotopes Division, USAEC, and on December 15, 1950 the first radioactive cutting tools ever produced were removed from their shipping container in our laboratories. The prime questions still to be answered before a routine tool-wear test method could be established were: (a) would most of the tool wear products be found on the chips? and (b) would the tool wear be sufficiently uniform that a wear-products sample resulting from a few seconds of experimental cutting would be representative of the actual rate of tool wear?

Experimentation with the radioactive tools quickly got underway and answers to the questions were obtained rapidly. Chips cut with the tools were found to be radioactive, and the level of activity was that which the calculations predicted for the total amount of tool wear products. If a small quantity of cutting fluid was used and recirculated for successive tests, it also was found to be radioactive, and this activity increased slowly with successive cuts. However, when activity of chips was compared with that of the cutting fluid, it was found that under usual cutting conditions better than 95% of the tool-wear products remained with the chips.

The uniformity of the wear process also has been investigated. Autoradiographs were made of chips cut with a radioactive tool, and these showed a quite uniform distribution of wear products along the chips. A typical autoradiograph is shown in Fig. 3. Likewise, chip samples taken from successive cuts with a radioactive tool under fixed conditions showed a uniform level of activity with only a normal random scatter of the results. However, over a period of a number of cuts it usually is observed that there is a long-range undulation of the level of activity of the chips—and thus of the wear rate.

Savings—$10⁹ Annually?

As the radioactive tracer method of measuring tool wear gradually takes its place along with such standard methods as hardness testing and chemical analysis, as a basis for establishing machining recommendations for production operations, its effect on the national economy can be foreseen to be profound. Experience shows time and again that careful application of accurate machinability information to almost any present-day routine production machining operation can effect a 50% reduction in machining costs with little difficulty. As a conservative estimate, widespread use of such a rapid and accurate tool-wear test as the tracer method might well reduce a nation's machining costs by 10% in the long run. In terms of the U. S. expenditure of $10-billion annually for machining, an eventual annual saving of $1-billion appears to be entirely possible!

Relative Wear

Because practically all the tool-wear particles remain with the chips and a uniform level of activity is found for these chip samples, measurement of the activity of the chips alone can be used as the basis for a tool-wear test method, thus providing the possibility for a very simple and quick procedure. Only the long-range undulation of the wear rate appears to introduce any problem.

However, since *relative* wear measurements are all that are needed for machinability information (comparing one material, or one set of conditions, with another), this apparent problem is eliminated by the simple expedient of alternating, on successive cuts, between the two materials or conditions being compared.

The simple arrangement used routinely, day in and day out, for the measurement of the activity of the chip samples, and thus for the measurement of tool wear, is shown in Fig. 4. Chips are placed in a Marinelli beaker and a heavy-walled gamma-counting G-M tube is inserted in the central cylinder. The count is recorded on a scaler. After correction for background it is reduced to terms of counts per minute per gram of chips as a direct measure of rate of tool wear. Normally ten successive cuts are taken, alternately, with each of the two materials or conditions being compared, ratios of the values are formed and averaged, and the uncertainty of the result calculated statistically.

Accuracy and Speed

In most cases, results are found to be accurate to $\pm 10\%$ or less, based on a 95% confidence limit. This can be compared with the accuracy of approximately $\pm 30\%$ normally found for conventional tool-wear-testing methods based on the same confidence limits. Thus the method is found to be not only more rapid but also more accurate than conventional testing.

Regarding rapidity, experience with the tracer method in the few years since its inception has shown that tool-wear data and information that would take a year to obtain by conventional methods can be obtained in 2–4 weeks by the tracer method! Improved and more sensitive instrumentation for routine use will further increase this advantage of the tracer method, since a large portion of the test time is still involved in the counting process itself.

Application

Since initial publication of the details of this tracer method of measuring tool wear in 1953,* its use in industry and research has increased rapidly. Today, to the authors' knowledge, the basic method is being used in at least eight organizations in this country, and facilities for using it are being installed or developed in at least nine other U. S. organizations. Further, the basic method now is being employed or is in process of being installed in organizations in a number of foreign countries, including Sweden, Germany, France, and Russia.

Cost Is Small

From the description of the development of this simple tracer method it is evident that the capital investment needed, over and above that for conventional tool-wear testing, is indeed small. It covers: (a) the scaler and related monitor, survey meter, and personnel dosimeters, (b) the remote-handling, tool-holding and tool-storage equipment and, (c) a small amount of standard laboratory facilities and equipment. It amounts to $5,000–$10,000, depending on the elaborateness desired. For this small capital investment, tremendous savings are realized, for tool-wear-testing time is reduced to $\frac{1}{12}$–$\frac{1}{25}$ its original duration, so that tool-wear-testing costs are correspondingly reduced. At the same time, the increased output rate of tool-wear-machinability information results in far greater savings in the production machining operations to which this machinability information is applied.

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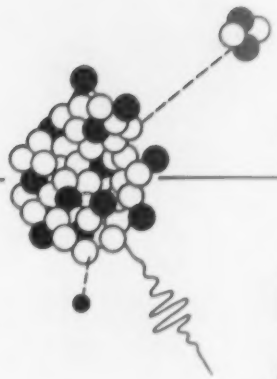

Improving Quantitative Analysis

By CHARLES ROSENBLUM
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THE TERM ISOTOPE DILUTION was first applied to the analysis of amino and fatty acids in biological media by means of tracer acids labeled with deuterium (*1*). Change in D/H ratio produced by equilibrating the labeled compound with the unlabeled form in the sample measures the quantity of acid present. Dilution of the stable isotope occurs in all such procedures since: (a) the natural incidence of stable isotope is significant, and (b) relatively large amounts of tracer usually must be employed to insure adequate sensitivity and sufficient material for analysis.

The difference between the straightforward radiometric correction and the isotope-dilution method lies in the need for the latter to subtract the quantity of labeled material added (*2-5*). This distinction readily can be illustrated for radioisotopes. Suppose that to a broth containing an unknown amount of vitamin B_{12} one adds a measured amount of radioactive B_{12} of known specific activity. After equilibration and isolation of a portion of purified vitamin, one has a quantity of B_{12} with a new specific activity. Recovery need not be complete, but the recovered product must be pure B_{12} or the spectrophotometric method applied to the isolate must represent only B_{12}.

The familiar isotope-dilution equation (see table) has the amount of tracer y as a subtractive corrective term. When $y \ll x$, the original amount of B_{12}, the second term drops out, leaving the radiometric-correction equation.

Tracer Activity

In effect, whether one uses an isotope-dilution calculation or a simple radiometric correction depends on the tracer specific activity. In vitamin B_{12} assays, only low-specific-activity tracer ($\sim$0.25 μc/mg) was employed initially (*6*), but subsequent preparation of vitamin with activities of $\gtrsim$1 mc/mg permitted using weightless quantities ($\sim$0.03 μg) for assaying samples containing several hundred micrograms (*7*).

Many other examples in organic and inorganic analysis attest to the method's usefulness. However, one should remember to compare the magnitude of the synthesis problem with the ease and reliability of conventional assay methods before resorting to the isotope procedure.

Where a separation process is incomplete, isotope dilution is the next logical step. What is more reasonable than to make an appropriate correction for incompleteness of separation or recovery?

The analyst can profit also from the example of the biochemist who studies metabolic pathways by administering a labeled compound and examining tissue and waste product for original precursor and its labeled metabolites. If the specific activity of a metabolite is the same as that of its labeled precursor, the quantity of this product is determined readily. With quantitative recovery, recovered radioactivity is a direct measure of product present.

The First Use of Tracer Dilution

As long ago as 1932 Hevesy and Hobbie used minute quantities of RaD as an indicator for lead to correct for incomplete anodic electro-deposition of PbO_2 in determining the lead content of rocks (2). *This is the first recorded use of an isotope-dilution procedure although, paradoxically, the extent of dilution of the radioactive lead was irrelevant.*

Reverse Isotope Dilution

Where quantitative recovery is difficult or the extent of recovery is unknown, one may still assay for a precursor or its metabolite by adding a measured quantity of unlabeled carrier and recovering a portion of purified and isotopically diluted product. Fractional recovery of inert carrier is used to correct the incomplete radioactivity recovery. The use of unlabeled tracers for determining recoveries of radioactive forms is common practice in activation analyses.

This method has been termed "reverse isotopic dilution" (*8*). Again the expressions that govern can be derived from the statement of constant radioactivity: $xS_0 = (x + y)S_f$ (see table).

When the original specific activity S_0 is unknown, it is still possible to do a series of simultaneous or successive dilutions and obtain an answer. This

Formulas for x, the amount of unknown component in a mixture

Method	*Formulas*	*Symbols*
Isotope dilution	$x = y(S_0/S_f - 1)$ $= yS_0/S_f - y$	y = amount of tracer added (mg) $S_0 = A$ cpm/y mg = specific activity of tracer $S_f = B$ cpm/z mg = specific activity of extracted sample
Radiometric correction	$x = yS_0/S_f = Az/B$ $(y \ll x)$	
Reverse isotope dilution	$x = \dfrac{y}{S_0/S_f - 1}$, or $= yS_f/S_0$ (when $y \gg x$)	y = amount of inert carrier added (mg) $S_0 = A$ cpm/x mg = specific activity of extracted sample before dilution $S_f = B$ cpm/z mg = specific activity of extracted sample after dilution
Derivative dilution	$= yB/zS_0$	y = amount of reagent added (moles) S_0 = specific activity of reagent (cpm/mole) S_f = specific activity of extracted derivative (cpm/mole)

is an experimental device for setting up two simultaneous algebraic equations in two unknowns and eliminating the unknown factor S_0. Double dilution has been proposed for amino-acid analysis, while successive dilution of a given sample for the assay of chrysene-5,6-C^{14} has been used in a yield determination (*8, 9*). This multiple dilution is of limited usefulness since excessive additions lead to algebraic identities.

With this method the stability of vitamin B_{12} in complex media has been shown (*10*). In essence, stability determinations are a series of analyses performed at a succession of time intervals. The simple expedient adopted was that of adding known small quantities (as low as 0.5 μg/oz) of vitamin B_{12}-Co^{60} to the medium, a dry cereal for instance, and subsequently recovering a portion of the residual intact vitamin after addition of a known large excess of crystalline vitamin as carrier.

Since the specific activity of the labeled vitamin is known, the residual intact material can be calculated from the measured activity of diluted vitamin recovered. The fractional residual vitamin is yB/zA (see table).

Derivative Dilution

In the use of dilution methods one need not be limited to the addition of labeled compounds of known specific activity to a system. With suitable radioactive reagents of known specific activity, any compound becomes, at least in principle, a candidate for analysis by the isotope derivative or "derivative-dilution" method (*11, 12*). The role of the radioactive reagent is to fix the specific activity of the unknown by forming a radioactive derivative. Of course, this assumes that reactions are stoichiometric, that excess reagent is removable, and that the desired derivative can be separated from incidental labeled products.

Although radioactive reagents had been used before in connection with inorganic precipitation reactions (*13–15*), more recent work has broached the field of organic analysis. Furthermore, the possibility of adding carrier derivative extends the dilution technique to include organic microanalysis. The mathematical expressions for reverse isotope dilution apply to derivative-dilution with the exception that quantities must be expressed in molar units. If the labeled derivative can be isolated quantitatively without a carrier, the recovered radioactivity divided by the specific activity of the reagent directly yields the quantity of the unknown.

The chief virtue of the derivative method is its sensitivity; a possible disadvantage is lack of specificity. To check the incompleteness of formation of a derivative or completeness of isolation without carrier addition, double labeling has been proposed (*11, 16*). However, it is doubtful that the analyst will find it necessary to resort often to such complicated, albeit elegant, alternatives.

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CASE STUDY

Measuring the Active Ingredient in an Insecticide

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When a separation process is nonquantitative, the isotope-dilution method often permits accurate analysis. Quantitative analysis for a component of a mixture is often needed when no quantitative isolation procedure is known. Particularly for complex organic mixtures it may be possible to isolate the desired compound with satisfactory purity, but in low and uncertain yield. In such case the analysis can be made by isotope dilution. The mechanism of the method is straightforward, consisting of four simple steps: labeling, dilution, separation, counting. The extent of dilution of the added labeled component by the mixture's unlabeled component, as determined by counting, will reveal the original quantity of unlabeled component.

Isotope Dilution—the Method

1. **Prepare** *a pure labeled compound of known activity, identical in chemical structure to the component to be determined.*

2. **Add** *a known quantity of the pure labeled component to a known quantity of the mixture.*

3. **Isolate** *a pure sample of the component from the mixture containing both labeled and unlabeled molecules.*

4. **Determine** *the specific activity of the isolated sample and apply the conventional isotope dilution formula, $X = A[(B/C) - 1]$, where X = weight of component contained in unknown mixture, A = weight of labeled component added, B = its specific activity, C = specific activity of isolated sample (1).*

The Problem

Let our problem be the determination of the gamma-isomer content in hexachlorobenzene, better known as BHC. The most used analytical methods are partition chromatography, polarographic measurement, and infrared absorption. In part they either require quantitative operation or are subject to interference from other chlorinated products normally associated with BHC.

The need for a more accurate method arose from wide-spread disagreement between state control laboratories and manufacturers of technical grade hexachlorobenzene when samples were checked by the laboratories. Since the price is based on the gamma content, large sums of money were sometimes involved.

With the availability of radioisotopes means were at hand to apply the convenience of radioactivity measurements to the advantages of the isotope-dilution technique—where no quantitative isolation is required and there is no interference from other isomers.

Labeling with Cl^{36}

Chlorine-36-labeled pure gamma isomer is used as the tracer, primarily because of the ease of affixing the labeling atoms to the molecule of BHC. This isotope is an excellent one because of its high emission energy and its long half-life. The cost is small. If the analyst prepares his own labeled gamma, the cost of Cl^{36} is about $4 per analysis.

About 5 μc of Cl^{36} are required to prepare 1 gram of chemically pure Cl^{36}-labeled gamma isomer having a specific activity of about 19 cpm/mg when a solution containing 5 mg/cm^3 of gamma isomer in acetone is counted with a glass liquid-jacketed counting tube with an inner-wall 25 mg/cm^2 thick. Such a tube, with all of the inner surface available to beta particles, has a counting efficiency of about 2.5%. One gram of pure labeled gamma isomer of this specific activity is sufficient for eight analyses of 1-gm samples containing 10–15% gamma isomer.

The isotope is purchased in the form of aqueous HCl^{36}. When unlabeled chlorine gas is passed into the radioactive HCl, unlabeled chlorine exchanges with the Cl^{36}, which is released and allowed to pass into benzene. There chlorination of benzene proceeds in the presence of light. The exchange, which is essentially quantitative, con-

Bear in Mind that . . .

1. *The labeled atom must be in an unreactive position so that exchange will not occur during isolation.*

2. *Isotopic effects (fractionation) should be at a minimum—especially in gases.*

3. *A procedure must be available for isolating a pure sample in quantities sufficiently large for counting.*

sists of the rapid establishment of equilibrium between chlorine and chloride ion in aqueous solution (*3–6*). The mechanism is formation and decomposition of the trihalide ion with a definite lower limit for the interchange velocity (*7*). After chlorination is complete, the benzene is distilled in a properly trapped, leakproof system. A residue of solid, crude, radioactive hexachlorobenzene remains which contains all the isomers.

To isolate the pure gamma, the crude cake is extracted with n-hexane, saturated with nitromethane, by heating to the boiling point and stirring thoroughly. The extract is decanted into a beaker, and the decantate is evaporated under a heat lamp until all the solvent is removed. A gamma oil concentrate remains.

The next step consists of a combined purification and dilution of the labeled gamma isomer. Preliminary radioactive measurement of a sample of gamma oil showed that the specific activity was higher by a factor of about 200 than is needed for ultimate use in an isotope-dilution analysis. A 200-fold dilution is introduced by adding pure unlabeled gamma isomer. The mixture is dissolved in 95% ethyl alcohol by heating and stirring and cooled to 20° C with constant stirring as crystals begin to appear. The crystals are filtered, washed, and dried. To assure purity the product is recrystallized several times until, by cryoscopic means, a purity in excess of 99.5% is demonstrated in the final dried product.

Dilution

About 120 mg of the labeled pure isomer of known specific activity is added to 1 gm of technical-grade BHC of unknown gamma content. Labeled gamma and unknown are weighed accurately to 0.1 mg. Through a series of extractions a pure gamma sample is isolated from the mixture. This is recrystallized until the proper melting point is obtained. Then purified crystals are dried in a vacuum oven for 2 hr at 70° C to remove all solvent. The yield in pure gamma is about 50 mg.

Specific activities of the added gamma and the isolated sample are determined by dissolving 50 mg of each separately in exactly 10 ml of acetone. Each is weighed accurately to 0.1 mg before dissolving. After thorough mixing the solution of isolated sample is siphoned into the counter tube with a hypodermic syringe until the inner chamber is completely filled and allowed to count for a total of 15,000 counts. The counting tube is thoroughly flushed with acetone and siphoned dry before determining the activity of the labeled gamma "standard."

Values obtained (cpm/mg) are then substituted into the dilution formula with the weight of added gamma. The result is the weight of pure gamma in the original mixture.

Accuracy

For good accuracy and precision the labeled pure gamma isomer should have a minimum specific activity of 1,000–1,500 cpm when 50 mg are dissolved in 10 ml of acetone (20–30 cpm/mg) using a counting tube with wall thickness of 25 mg/cm^2. The resulting isolated sample will then have a specific activity of 500–700 cpm for a 50-mg sample. Ten times background is usually regarded as the minimum counting level, and normal background for this type of tube with an acetone blank is usually 40–50 cpm. The method is inherently absolute as long as the conditions are known and controlled.

Uniformity of Results

The method was tested by preparing a quantity of synthetic BHC containing known amounts of all the isomers normally found in technical-grade BHC. The calculated gamma content of the synthetic mixture was 14.0%. Six determinations were made by three different analysts. The first two samples were run by a laboratory technician; the next three, by an experienced analyst. The sixth sample was analyzed by a person with no previous experience in analytical problems. The data indicated the accuracy of the isotope dilution technique (*2*). Calculated gamma content was 14.0% and the mean value for the 6 determinations was also 14.0%. The range was 0.20% and the standard deviation was 0.09%.

Next, commercial technical-grade hexachlorobenzene was analyzed by this technique. Six determinations were made. The mean obtained was 13.9% gamma. The range was 0.40%, and the standard deviation was 0.15% (*2*).

Another set of experiments was run to show the comparison of the Cl^{36} analysis with the infrared method. A sample of technical hexachlorobenzene was circulated to five companies for analysis by infrared. An average infrared value of 13.3% gamma was obtained with a standard deviation of 0.1%. A single determination made by the Cl^{36} method showed a value of 13.3% gamma (*2*).

A number of collaborative studies have since been conducted to further test the application of the isotope dilution method to the gamma analysis. Six different laboratories have participated and agreement has been outstanding.

The method is presently being investigated by the Association of Official Agricultural Chemists for its adaptability as an official referee method for the analysis of gamma isomer in hexachlorobenzene.

Safety

The fact that Cl^{36} is a beta emitter virtually eliminates shielding problems. However its long half-life means that care must be taken to prevent inhalation of chlorine gas during synthesis of labeled BHC. Tightly fitting connections in the apparatus and a well ventilated hood provide necessary precautions.

Gamma BHC

The gamma isomer is found as a colorless, monoclinic crystal having an axial ratio (a:b:c) of 1.51:1:1.35. This compound is practically insoluble in water, soluble in many organic solvents, odorless, and it has a sharp melting point of 112.5° C. It is a stable compound, except that in the presence of alkali, HCl is removed from the molecule—giving a mixture of isomers of trichlorobenzene. The gamma isomer is prepared, with the others, by reacting chlorine with benzene in the presence of light. It can be separated in the pure form by solvent extraction or chromatographic separation, but it is difficult to do so quantitatively.

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Radiation Measures Density

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INCREASED AVAILABILITY of relatively inexpensive radioisotopes, the development of rugged, stable, low-noise radiation detectors, and other advances in instrumentation techniques have brought radioactivity density and thickness gages into a large number of manufacturing and process industries (*1–5*).

Between 600 and 800 gamma-ray gages are in continual use in all types of industries from pharmaceuticals to glass and from food to petroleum. They are measuring and controlling the levels of liquids, and the density or percent of solids in slurries.

Radioactivity gages are becoming more and more popular because their many advantages result in higher quality products at lower costs; this more than compensates for their somewhat higher initial price.

For example, in the cement industry closer control of the density of a clay-water slurry, effected by the use of this type of instrument (see Fig. 1), has made it possible to increase production. In addition, maintenance costs resulting from the slurry becoming too thick and plugging pipes and pumps have been reduced. Fuel costs are lowered by operating with a minimum amount of water in the slurry.

Isotopes Used

In all but one of applications listed here, cesium-137 is used because the relatively low energy of its gamma radiation (0.662 Mev) and its rather long half-life (33 yr) result in high sensitivity and stability.

Cobalt-60 is used to measure the level in the thick-walled vessel because in that application lack of stability resulting from Co^{60}'s short half-life (5.3 yr) is not as important as the penetration ability of the high-energy gamma rays (1.17 and 1.33 Mev).

Increasing Sensitivity

Radioactivity density gages *do* have some disadvantages. It is quite frequently necessary to use large samples to obtain the requisite span and precision of measurement. This is because gamma absorption is a function of the thickness of the sample. (See Fig. 2.) Inserting an expanded section of pipe in a smaller line is a way of getting around lower sensitivity at smaller pipe size. However, to employ this technique successfully, the expanded section must be installed in a vertical position to avoid stratification of the solution or slurry (Fig. 3).

Recent Developments

Until about one year ago, radioactivity gages were limited in precision to relatively rough measurements. For example, when installed on a 10-in.-diameter pipe full-scale range was 0.100 sgu (specific gravity units) with a precision of 0.002 sgu (2% of scale). As a result of improvements in equipment and components, it is now possible to obtain a range of 0.05 sgu full-scale on the same size pipe with a precision of 0.00025 sgu.

Another development in the field that promises to be quite significant is in the application of automatic temperature compensation to provide normalized specific gravity readouts in spite of variations in product temperature.

Radioactivity gages have completely bridged the gap between the laboratory and industry. They are valuable and proven process-control tools that are solving many problems in industry with resultant product improvement,

These Advantages of Radioactivity Gages . . .

External location. *In most applications, all measuring components are located outside the pipe or tank containing the material to be measured. Thus, internal conditions—high or low temperature, abrasion, corrosion, viscosity and agglomeration—do not interfere with the measurements.*

No moving parts. *Gages are exceedingly rugged, offer long life and low maintenance cost.*

Easy to install. *External installation is simple and economical and does not interrupt the process.*

No sampling tubes. *Sample is measured directly in process vessel, thus there are no side-sampling tubes to plug. Sampling problems produced by laminar flow are eliminated.*

Insensitive to turbulence. *Gages are completely insensitive to flow-rate variations and turbulence as long as density characteristics are not altered.*

Sanitary. *Gages are completely sanitary; this is important with foods.*

Safe. *There is no danger of radioactive contamination as long as the externally located capsule containing the radioactive material is adequately sealed. In addition, the energy of the radiation that is emitted from the source is too low to induce any artificial radioactivity in the product.*

Stable. *Calibration stability is limited only by source decay.*

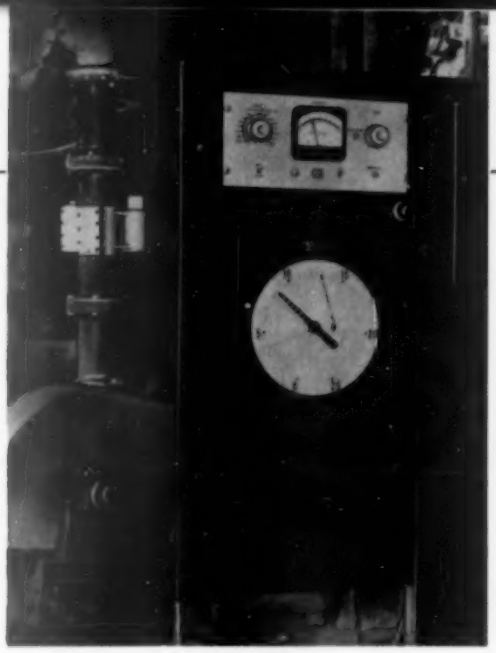

FIG. 1. Radioactivity gage used to measure density of slurries

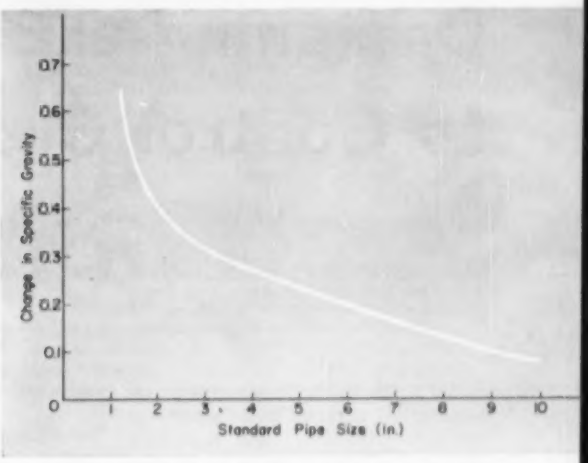

FIG. 2. Minimum absolute specific-gravity change that can be detected decreases with increasing pipe size. Curve is for specific gravities near that of water

increased production rate, and lower product cost.

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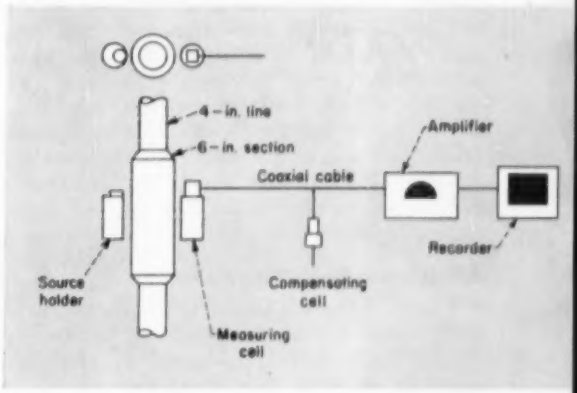

FIG. 3. Effect shown in Fig. 2 can be overcome by widening pipe at the point where density is measured, as shown here

. . . Have Led to Applications Like These . . .

Solids in slurry. *Measurement of solids in an asbestos-cement-water slurry in a 6-in. steel pipe over a range of 0–20% solids, (1.0–1.2 specific gravity units) with a precision of 0.4% solids (0.004 sgu). This type of gage was selected because of its complete freedom from deleterious effects caused by abrasion and agglomeration. Gage is shown in Fig. 1.*

Sulfuric-acid concentration. *The measurement and control of the concentration of sulfuric acid over a specific-gravity range of 1.00–1.10 in a 10-in. Hastelloy pipe covered with 2 in. of insulation. By applying the gage output to a pneumatic controller it is possible to control the concentration of the acid to 0.001 sgu. In this case, the gage was chosen because flow effects and sampling errors, together with the corrosive nature of the sulfuric acid, had made other types of controllers unsatisfactory.*

Evaporator control. *The control of the output of an evaporator to maintain the percent of solids of a spent mash slurry at a constant value. Prior to the use of a radioactivity gage, the high viscosity and plugging characteristics of the material ruled out other types of instruments.*

Level control. *The measurement of liquid level in a high-pressure, high-temperature reactor, with 2¼-in. steel walls covered with 2 in. of insulation. The purpose of the gage is to sound an alarm when the high level is reached and automatically shut down the process if corrective action is not taken within a predetermined length of time. Radioactivity gage proved more economical and less troublesome than a float system operating through high-pressure seals.*

Interface location. *Gage detects the position of an interface between isobutane and gasoline in a product pipe line. Audible alarm alerts the operator when an interface passes. Radioactivity gage was used in preference to a mechanical system because it responds more rapidly to the interface and there are no side-sampling tubes to plug and give erroneous indication.*

CASE STUDY

Designing a Beta Gage to Control Cigarette Density

By C. S. McARTHUR
American Machine & Foundry Co., Raleigh, N. C.

ABILITY TO CONTROL cigarette uniformity to narrow limits results in raw-material savings and minimizes customer complaints that stem from off-standard products.

To produce evenly packed cigarettes, a feeding mechanism must deliver a uniform stream of tobacco to the section of the machine that makes the cigarettes (applies the tobacco to the paper, forms it into a continuous cylinder, seals, and finally cuts the cigarettes to the proper length). A dielectric system had been used to measure the cylinder being produced, but its stability was somewhat below that required for automatic control.

Applying a Beta Gage

A stable means was needed for accurately measuring the weight of cigarettes as they were being produced. A feasibility study was initiated on using a beta-gage-type of measurement for this operation. Beta gages were in use at the time the investigation began, but mostly they were used to measure the thickness of materials in plane form—such as paper and foil. Little was known about the science of measuring the density of a small cylindrical rod moving at high linear velocity. With a suitable electrometer-amplifier available commercially, a measuring-head design was started.

Accuracy. For the instrument to be automatic in action, the measurement must be relatively free of drift for prolonged periods. The accuracy required for this measurement was determined by the 0.25% deviation allowable in the mean weight of cigarettes. Although this figure was established somewhat arbitrarily, it was apparent that an accuracy of 0.25% allows marked improvement over manual control.

Selecting an Isotope

The ideal cigarette represents ~180 mg/cm² to the beta rays. The choice of the isotope for this application was not difficult since the characteristics of strontium-90 stood out as the most suitable from several standpoints. Of the available beta-emitting isotopes with a reasonable half-life (>2.5 yr), only thallium, strontium, and chlorine had the desired beta energy with little or no gamma activity. Chlorine and thallium energy characteristics were on the minimum side considering the absorption of the windows in the source and ion chamber. Thus, the strontium-yttrium combination with 2.18-Mev betas was chosen.

Amount of isotope. The quantity of Sr^{90} needed was determined through a balance of two factors—we wanted a reasonably high sensitivity, yet the level of radiation at the measuring point outside the head was to be kept within tolerance without excessive shielding.

The head sensitivity was to be high enough to eliminate the need for extremely high gain in the amplifier, yet allow the control mechanism to be operated at a reasonably high level. The cigarette plus additional protective absorber represents ~200 mg/cm². This amount of absorber for Sr^{90} is in the maximum-sensitivity range. This is the region of absorber weight that gives the greatest change in ion current in the detector for a given change in absorber mass.

To aid in determining the isotope quantity required, an experimental ion chamber was constructed around the physical limitations allowed by the space available. A 15-mc source was available for the experiment, which showed that for a 1% change in cigarette weight, an ion current change of 1.25×10^{-11} amps was produced. This gave the information needed to determine the range of amplification and input resistance needed for a reasonable signal level. Also, it established the fact that 15 mc of Sr^{90} was adequate.

Designing a Collimator

The first approach took the form of two stainless-steel guides of $2\frac{3}{4}$-in. length, with machined concave faces to fit the cigarette rod. The gap between

Choosing a Detector

The first step in the beta-gage design was to determine what type of detector to use. The scintillation gage, Geiger-Müller detector, and ion chambers were considered.

Scintillation gage. *Although extremely sensitive, the scintillation gage has some disadvantages: (a) its stability is difficult to maintain; (b) at the time of the investigation, the physical construction of photomultiplier tubes did not allow for operation under vibration and general abuse.*

G-M tube. *The G-M detector was discounted because of several factors: (a) resolution accuracy for short-term measurement is inadequate; (b) tube life is limited—making frequent replacement necessary; and (c) the need for high voltage.*

Ion chamber. *Many such systems are in use on density gages and, excluding the insulation problem for the collector, no real obstacle was apparent when the decision was made to use this method of detection.*

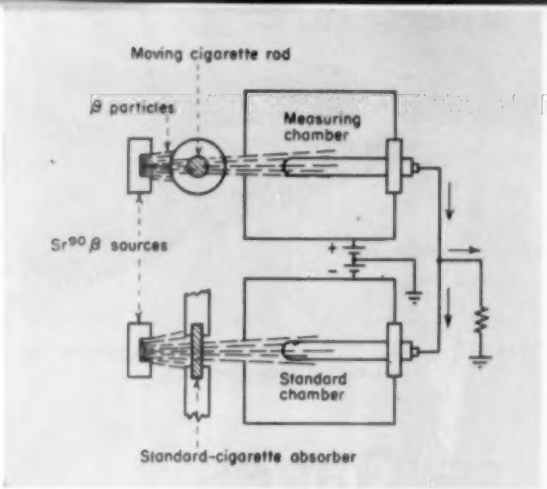

FIG. 1. Dual-source-chamber measuring head compensates for temperature changes. Ionization voltage for each chamber is equal in magnitude, but opposite in polarity. With common collector, system causes opposite and cancelling effects when temperature changes

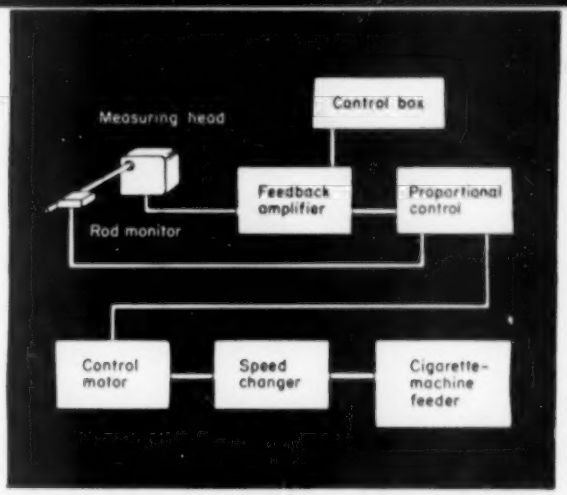

FIG. 2. Machine feeder is controlled by electromechanical speed-changing mechanism, which is actuated by a proportional control system coupled to a stable amplifier getting signal from measuring head. Rod monitor disconnects regulating system when cigarette rod is not in motion

the two bars was $\frac{1}{4}$ in. Since the cigarette rod has $\frac{11}{32}$ in. dia., the gap masks particles entering the rod. Geometrically, the measurement includes only the center section of the rod and, discounting scatter, only 90% of the rod is exposed to the electron beam. This restriction was made so that the full radiation could not pass at the edges if the rod diameter should become smaller than normal.

Making the Measuring Head

For the sake of safety from gamma-like bremsstrahlung radiation, the measuring head was made of low-density material. Aluminum was used because of its machinability and availability. The maximum range of the most energetic particles from Sr^{90} is ~1,100 mg/cm². Thus, with an absorption of 6.8 mg/cm² per 0.001 in. of aluminum, the minimum thickness of housing with direct exposure to the rays is $\frac{5}{32}$ in. Bremsstrahlung level at the surface of a given design was not determined easily since the high-density materials in the head design were not distributed uniformly. This made calculation impractical before the design was complete.

Although cigarette plants normally are air conditioned, air temperature varies somewhat. Also, the cigarette machine itself has an orderly variation in temperature because of the frictional heat generated in the gearing and mechanism. Thus the system should have a temperature-compensating feature. Such a system is shown in Fig. 1.

Mounting the Head

With the functional design features of the measuring head established, its physical design is somewhat limited by the available space on the cigarette machine. The most convenient and practical point for the measurement is at a point just prior to the cutting operation where the rod is completely formed. In all makes of cigarette machines considered, the space behind this rod is only 1 in. The space along the direction of the rod is ~4 in. Other planes are not so restricted. To a great extent, these dimensional restrictions determine the volume available for the ion chambers.

The first approach was to design the system around a nitrogen-filled and sealed ion chamber at the cut-off with an adjacent sealed chamber for balance. The source-chamber measurement was through the cigarette rod in a horizontal plane to minimize dust collection on the horizontal window surfaces. Hermetically sealed sources were mounted in a plate behind the rod that was integral with, or attached to, the bed of the machine. The chamber housing was hinged to allow access to the windows for cleaning. For safety, this hinge and associated mechanism were designed to operate an automatic shutter. The cigarette rod was guided through the head by a bell-shaped entrance mouth.

Tests and Modifications

This experimental model was tested and found to deliver a current proportional to the weight of cigarettes.

The tests revealed several minor problems; subsequent models were designed to eliminate the difficulties. The solid collimating guides often collected dust at the windows as well as paste and moisture droplets on the surface of the guides. These problems are solved by using a guide tube whose inside diameter is large compared to the cigarette rod and yet does not allow dust and moisture to collect on critical surfaces. A stainless-steel liner seals off the source and chamber.

Errors also were introduced due to rod position and to changes in the cross-sectional geometry. In sealing the cigarette, the sealer sometimes presses the cigarette into a rod of elliptical cross section with the major axis parallel to the betas' path. This effect was partly counterbalanced by the bypassing of the beta particles along the rod edge as the cigarette becomes flatter. To minimize the effect of cross-sectional geometry in the measurement, the "beam" of particles from the source is shaped to provide a more uniform distribution of particles in the measuring area. This is done by selectively pre-absorbing betas at the source.

Conclusion

With the improved quality available with controlled machinery, cigarette manufacturing has become automatic as regards weight regulation.

Beta-gage control of cigarette machines has produced a reduction in the standard deviation of the product (short term) to one-half that attained with the most careful manual control. Also, the ability to maintain the daily mean weight of cigarettes to within 0.2% has been accomplished through the use of the beta gage. It is because of these results that most cigarette manufacturers have equipped their factories with beta-gage systems.

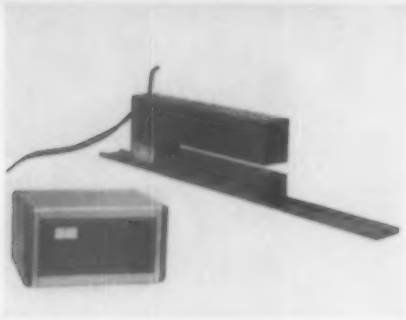

FIG. 1. Laboratory-type absorption gage

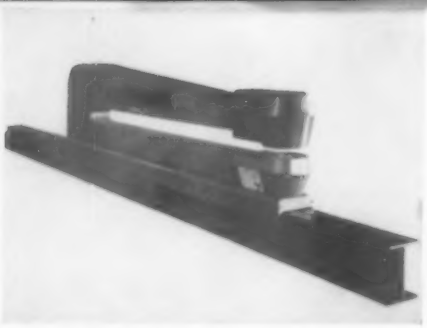

FIG. 2. Production-line source-detector configuration for absorption gage

Industrial Thickness Gages

By GEORGE B. FOSTER
Industrial Nucleonics Corp.
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CONSIDER the staggering quantity of material produced in continuous sheet form—paper, plastic, metal, textile, and abrasives are only a few. In every case standards of quality are strict. It is not difficult to appreciate the tremendous significance of an automatic, continuous, noncontacting gage using radiation to measure and control product thickness. Typical improvements in process control upon instituting radioactive gaging are listed in the table.

What is Measured?

The property usually measured is the weight per unit area of sheet material or the weight per unit volume of certain shapes. The weight per unit area varies all the way from 6 lb/ream (1 mg/cm²) for light-weight papers or 0.00025 in. of plastic film (0.6 mg/cm²) to heavy steel and titanium plate being processed through rolling mills. Thus, the range of radioactive source energies must be great.

Inspection Gage

The simplest gages are those used for inspection.

Figure 1 shows one type of technician-operated inspection gage. The slide base for the source-detector frame permits the equipment to be temporarily clamped to the frame of a processing machine. The radioactive source is mounted in the lower arm of the C-shaped frame, and an ionization-chamber detector is mounted in the upper arm. The sheet material passes horizontally between the two arms. The 2½-in. air gap permits the insertion of a wide variety of materials. A recording millivoltmeter can be plugged into a socket on the rear apron of the instrument case to provide a continuous record for process-machine studies and evaluation.

Automatic Control

Manual adjustment carried out by a machine operator in response to an indicating meter or chart can be used to control some processes. However, the present trend of industry is toward automatic adjustment of the processing machine to correct deviations from specifications set into the gage-controller combination.

The performance of the automatic-control system depends on the signal-to-noise ratio, step-function response, and long-term stability of the inspection device as well as the transportation lag between it and the point in the process at which the corrective actions required are carried out.

Automatic control improves process control further, as the table shows.

Isotopes Used

Usual compromises result in the use of strontium-90 for measurements in the range 10–600 mg/cm² and thallium-204 for the range 1–50 mg/cm² in absorption applications. Source strengths range from 5 mc to 1 c.

For heavier materials, various gamma emitters must be used. The choice is dependent on specific activities obtainable, energy distribution, cost, half-life, availability, and delivery.

How Radiation Gages Improve Process Control

		Process control (*2σ limits, i.e. 95% correlation*)		
Industry	*Application*	*Conventional control**	*Radiation gage, manual control*	*Radiation gage, automatic control*
	Fourdrinier machine	±12%	±10%	±3%
Metals	Tandem cold-roll mill	±10%	±7%	±1.5%
Rubber	Sheeting calender	±10%	±6%	±3.2%
Rubber	Tire fabric calender	±6.5%	±5.5%	±3.5%
Plastics	Calender	±7%	±3.5%	±2.5%
Impregnation	Saturator dip coater	Automatic control 2.5× better than conventional		
Abrasive	Abrasive maker	Automatic control 2× better than conventional		

* Conventional control is normally via a sampling method.

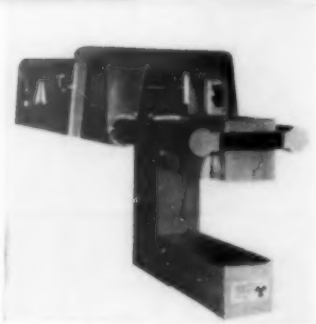

FIG. 3. Rugged source-detector frame mounting for rolling mill use

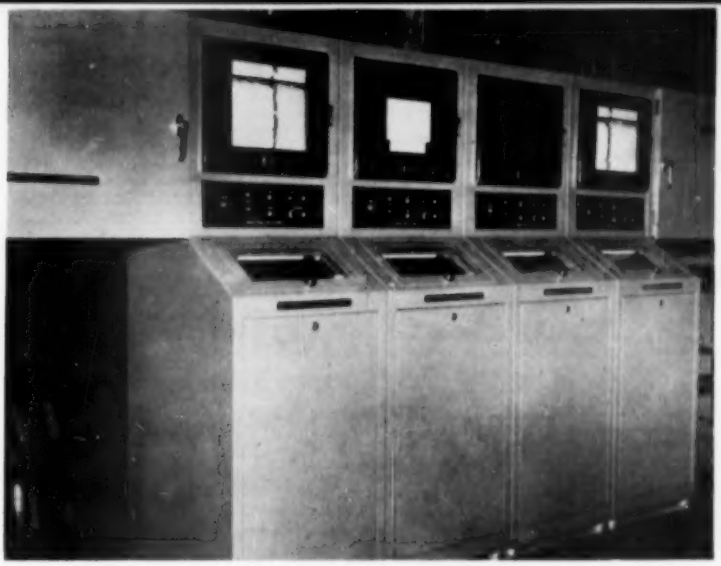

FIG. 4. Measurement, automatic-control, and readout equipment used in rubber plant

FIG. 5. Source-detector assembly for cigarette making

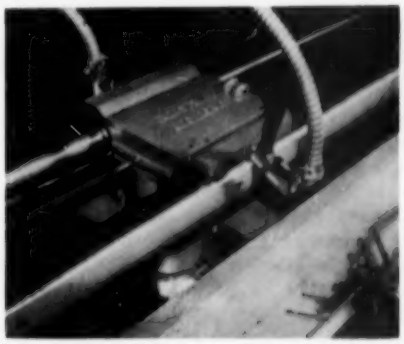

FIG. 6. Backscatter head mounted for scanning width of galvanized-iron sheet

Figure 2 shows a typical source-detector configuration for measurement of materials in the low-weight range. The frame is motor-driven on its supporting rail to permit profiles to be obtained across the width of a sheet material while it is being produced. The radiation geometry for these profile machines varies with the application. One needs high resolving power for studying profile variations in extruded plastic, but large measurement areas to average out formation effects in paper making.

To accommodate thicker, wider sheets one needs larger C frames to support detector and source. Frames have been built with throat depths as great as 12 ft. The limiting factor is the space available for installation rather than any deflection of the supporting arms or other causes.

Figure 3 shows a source-detector configuration commonly used for measurement and control in metal rolling mill applications. The contrast in mechanical design to Fig. 2 is considerable.

Figure 4 shows a typical installation of measuring, automatic-control, and data-readout equipment in a rubber-processing plant. The sensing element in this system is like that in Fig. 2.

Further extension of the technique into more specialized fields is illustrated by the source-detector assembly shown in Fig. 5. This unit mounts on a cigarette-making machine.

Sensitivity

The full available sensitivity of gages for light-weight materials cannot be utilized practically. This comes about because of errors produced due to changes in the environment of the measuring air gap.

Atmospheric air at STP represents an equivalent mass absorption of 3 mg/cm² per inch of path separating the radiation source from its detector. With ½-in. air gaps in use today on some installations, a limit on the available accuracy is imposed by the uncontrollable and uncompensable variations in the mass absorption equivalent of the air gap. Schemes for differentially exposing two sources and two detectors to the same environment with the measured material passing through one help to some extent, but even they become limited in their ultimate accuracy because the two source-detector combinations cannot see *identical* environments.

Backscatter Gages

Our discussion has been limited to transmission gages. To scan across the entire width of the widest paper making machines would require prohibitively big C-frames. Backscatter gages circumvent this difficulty since they measure from one side of the sheet.

The physics of the backscatter measurement depend on the difference in beta-radiation reflectivity between the backing substance and the measured material. When these two substances differ sufficiently in atomic number and are sufficiently homogeneous the method has many advantages. In the application of beta backscatter measuring heads it is extremely important to be fully aware of any possible errors due to uncompensable effects that arise through changes in the composition of the measured material.

Figure 6 shows the technique applied to the measurement of zinc coating applied to steel strip in the manufacture of galvanized iron. The successful application of this measurement technique for routine use in mill environments is a major engineering accomplishment.

Following Large-Scale Processes

By V. P. GUINN
Shell Development Company, Emeryville, California

LARGE-SCALE radioactive tracer studies are now readily feasible and are being undertaken to a greater extent all the time. Modern scintillation counting methods have extended and facilitated such work immensely, because of the great concentration sensitivity of such methods (*1*). Ten dollars worth of tritium (100 mc) can be diluted with 50,000 barrels of hydrocarbon and still be detected accurately by the liquid-scintillation method (*2*); and $10 worth of a typical gamma-emitter (10 mc) can be diluted with 600,000 barrels of liquid and still be detected accurately by a scintillation dip-counter. Since a large refinery processes about 100,000 barrels of crude oil per day, refinery-scale tracing is feasible. See figure.

The scintillation-counter methods not only possess the desirable feature of higher sensitivity, but also permit one easily to count several isotopes simultaneously for multiple tagging.

The use of scintillation counters in full-scale industrial radioactive-tracer studies is just beginning to become widespread, in spite of the much higher concentration sensitivity they provide. The variety of large-scale studies is indicated here, but most of these have employed G-M counters.

Catalyst mixing and stack-loss rate studies, similar to the Shell Development studies, have been reported by the Texas company (*3*). Earlier, catalyst flow rate was studied using Zr^{95} tagged catalyst beads in commercial Thermofor and Houdriflow catalytic cracking units (*4*). Tracers (Ba^{140} compound) have been used to study entrainment occurring in refinery vacuum flashers (*5*). Pipeline interfaces are marked with radioactive materials (Ba^{140} and Sb^{124} compounds) (*6*); in some cases, such interfaces have been followed for over 500 miles.

Water-flood operations in oil field work have been followed by the use of Co^{60} and I^{131} (*7*). Acidizing of oil wells has been controlled by using tracers (*8*). A number of other oil field tracer studies have been made (*9*).

The tracing of gas flows on a full commercial scale also has been carried out. Radon has been used to measure gas transit times in blast furnaces (*10*); H^3 and Kr^{85} have been used to follow the gas flow in oil-field gas-injection operations (*11*); and Kr^{85} has been used in air-mixing studies of fluid catalytic-cracking-unit regenerators (*12*).

As scintillation counting becomes more widespread, such applications will become more numerous and even more striking.

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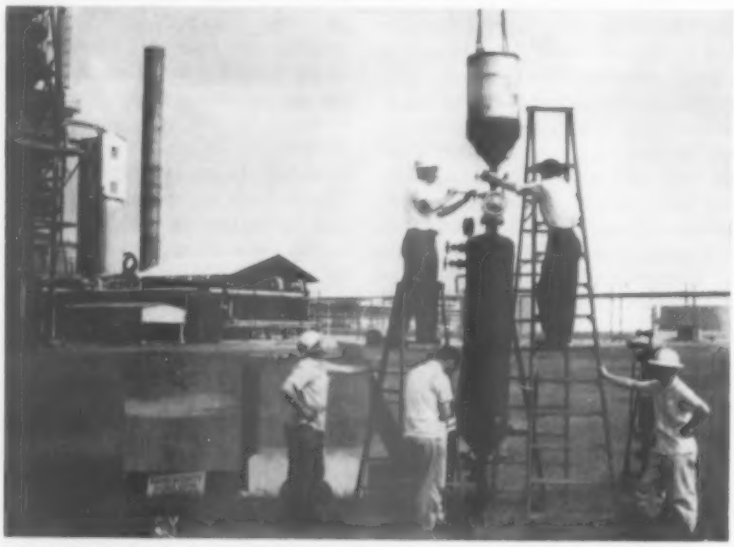

TRANSFERRING radioactive catalyst to injection vessel. Fluid catalytic cracking unit is at far left

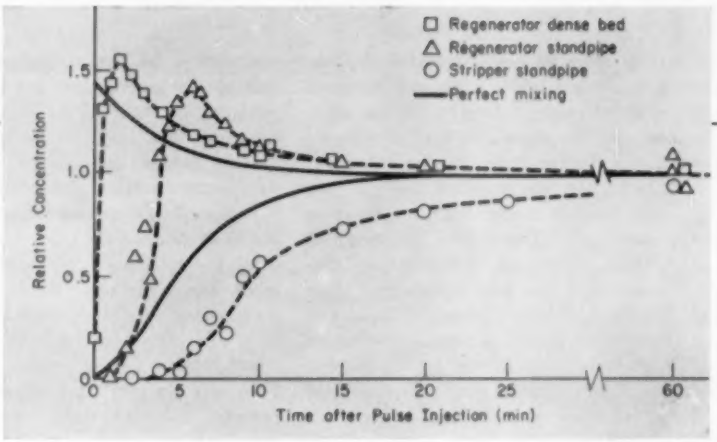

FIG. 1. Results of regenerator catalyst mixing studies. Solid curve represents theoretical behavior for idealized case of instantaneous and complete mixing in each vessel in the unit regenerator-reactor-stripper, with plug flow in lines connecting

CASE STUDIES

Tracing Catalysts in Refinery Crackers

By V. P. GUINN
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RADIOACTIVE TRACER methods, using high-sensitivity scintillation counting, have helped solve two problems in operating refinery catalytic-cracking units: (a) mixing behavior of fluidized catalyst, and (b) deactivation* of fresh catalyst. This work typifies our large-scale industrial tracing projects, made possible by sensitive counting.

The isotope, counting, and safety requirements for the two studies are given here. Generally, the requirements are more complicated for the deactivation studies. Typical results are given for the mixing studies only.

Isotope Choice

Any isotope used in catalyst mixing studies must be nonvolatile under the high oxidizing temperatures (~600° C) of the regenerator, the high reducing temperatures (~500° C) of the reactor, and the high steam temperature (~500° C) of the stripper. Although it is possible to prepare silica-alumina gel incorporating the desired radioisotope in the gel structure itself, it is much simpler to use an isotope that can be adsorbed on the surface of a commercial cracking catalyst. Preferably, the isotope chosen should be a gamma emitter of moderate half-life (of the order of weeks).

Deactivation. In deactivation and stack-loss studies two further criteria apply: (a) the isotope should adsorb uniformly over the entire tagged catalyst surface, and (b) it should be available in fairly high specific activity.

If the isotope does not uniformly adsorb over the catalyst surface, the catalyst particles will contain more isotope on the outer portion of the particle surface and less on the "walls" of the inner pores. This condition results in a disproportionate loss of radioactivity as the catalyst undergoes attrition in the catalytic cracking unit, the fines† produced soon being lost out the stack. To be sure that a fresh catalyst tagged for deactivation studies in a commercial unit shows a uniform distribution of the isotope, a sample is first examined in a fluidized-solid attrition tester. If uniform distribution is achieved, the fines produced by attrition will have the same activity per gram as the residual particles (assuming that catalyst surface area per gram is independent of particle size). A nonuniform distribution can be tolerated, but necessitates the application of correction factors, which is tedious and somewhat inaccurate. The attrition test also assures that no change in the catalyst's resistance to attrition has occurred in the process of labeling and drying the catalyst.

The isotope should be available in fairly high specific activity because, in

* "Deactivation" denotes loss of cracking activity, surface area, and pore volume —resulting from the exposure of the catalyst to the high temperatures of a catalytic cracking unit. We also studied stack-loss rate of catalyst using tracers. The catalyst referred to here is of the silica-alumina acid-type, a typical one containing ~87% silica by weight and 13% alumina, when dry. Average particle size is ~75 microns.

† Fines are very small particles.

tagging a small easily-handled batch of catalyst with the requisite amount of radioisotope, the amount of element present must be insufficient to produce any change in the catalytic properties of the tagged material. It is well known that more than 5–20 ppm by weight of certain metals will alter the cracking and regeneration properties of the catalyst, thus possibly changing its rate of deactivation in use. To label 50 lb of catalyst with 40 mc of isotope without exceeding a metal content of 5 ppm, specific activity in excess of 350 mc/gm is needed. In the deactivation studies, a small sample of the tagged catalyst is tested in a laboratory catalytic cracking unit to be sure that its catalytic properties are exactly the same as those of untagged catalyst.

Since one wishes to follow the deactivation of fresh catalyst in a commercial unit for a period of a month or more, and there are delays involved in the shipping of catalyst samples and in carrying out the sink-float separations, an isotope with a half-life of the order of a few months, rather than weeks, is preferable. On the other hand, it is not desirable to employ isotopes with half-lives of the order of years, since one may wish to carry out additional tracer studies in the same unit at a later date. For this same reason, and for safety, it is desirable to use as little radioisotope as reasonable.

To date, three satisfactory isotopes have been found and used, namely, Ce^{144}, Cr^{51}, and Sc^{46}. The main relevant properties of these isotopes are summarized in the table.

Tagging Method

The three isotopes have been found to be adsorbed strongly onto the surface of either fresh or "equilibrium"* silica-alumina cracking catalyst from a somewhat acidic aqueous solution of the trichlorides. Tagged catalyst, after drying, has shown no loss of radioactivity during 2 hr heating in air at 1,000° C—the adsorbed isotopes are not volatile under high temperature conditions. The known chemistry of cerium, chromium, and scandium indicates that the free metals and their oxides, hydrides, nitrides, carbides, and carbonyls would be nonvolatile under the conditions of use in commercial units. In studies carried out to-date in commercial units no evidence of volatilization of these isotopes from the catalyst surface has been found.

Uniform distribution of these isotopes over the entire catalyst surface can be achieved under certain conditions. The isotope studied most, Sc^{46}, distributes itself almost uniformly if catalyst is merely stirred for several hours with a small excess of almost neutral (pH ~6) aqueous solution of $ScCl_3$. At a pH of about 4, distribution is essentially perfect.

Sensitive Counting

Highly sensitive scintillation counting avoids the use of relatively hazardous quantities of radioisotopes (*1*). It was computed that 1 mc of a 1-Mev gamma emitter uniformly mixed in 500 tons of catalyst will produce a net counting rate of 275 cpm/kg above a shielded-counter background of 200 cpm, when 1-l samples are counted with a 2-in. NaI(Tl) crystal scintillation dip counter, with the crystal located at the sample center. This corresponds to an over-all counting efficiency of 7% (including geometry, self-absorption, and gamma absorption in the crystal). If both background and sample-plus-background are counted for 10 min, the net counting rate of 275 cpm/kg is determinable to 3% statistical accuracy. (If a very small weight of tagged catalyst is injected, the number of tagged catalyst particles in the sample counted also contributes to the statistical uncertainty. In general, this is not a large contribution to σ if 1-l samples are counted, but may be important if ~5-gm samples are counted, as in the well-counter method described below.)

In the catalyst-mixing studies carried out at three Shell Oil refineries, tagged catalyst containing 0.1–2 mc per experiment has been used successfully in units containing 60–850 tons of catalyst. In each case 1-l samples were counted with a large crystal scintillation dip counter immersed in the sample. Counting times are 5–20 min per sample.

Deactivation. In the catalyst deactivation studies, time-consuming separations make it difficult to prepare large samples for counting. For this reason, a well-type scintillation counter with a 2-in. NaI(Tl) crystal with a hole sufficient to accommodate 5-gm samples is used. With this method of counting it is advantageous to use a low-energy gamma emitter, since gamma absorption by the crystal increases as the gamma-ray energy decreases (self-absorption in the sample is small).

Two more complications in the deactivation studies necessitate larger amounts of radioisotope. One is that the samples are taken as long as one or more months after the original injection of tagged catalyst. In a 500-ton unit operating with catalyst being added at 10 tons per day (to balance stack loss of fines and periodic withdrawals), only 55% of the original amount of radioisotope would remain in the unit after 30 days. If the isotope employed has a 100-day half-life, this percentage is decreased to 45%. The second complication is that the initial rate of stack-loss of fresh catalyst is relatively high, frequently amounting to as much as 20% during the first few days. Thus, in the example cited, one might have to employ about 40 mc of a 0.1-Mev gamma emitter, instead of the 14 mc cited above, if one wished to follow the deactivation for one month. If a G-M counter were used, 2,000 mc would be required.

Safety Considerations

Hot catalyst is introduced by a trained radiochemist so that refinery operating personnel are not exposed to ionizing radiation. This operation has been carried out frequently with-

* The term "equilibrium catalyst" is used to denote plant-regenerated inventory catalyst in a commercial cat cracker. It contains catalyst ranging in age from a few minutes to many months and has an average surface area of about 100 m^2/gm.

Tracers Used in Catalyst Studies

Isotope	*Half-life, (days)*	*Principal gamma (Mev)*	*Max. spec. activity available (mc/gm)*	*Cost ($/mc)*
Ce^{144}	282	0.13	carrier-free	1
Cr^{51}	28	0.32	>25,000	5
Sc^{46}	85	0.89, 1.12	>5,000	3

The Problem—Trace Catalyst Mixing and Deactivation

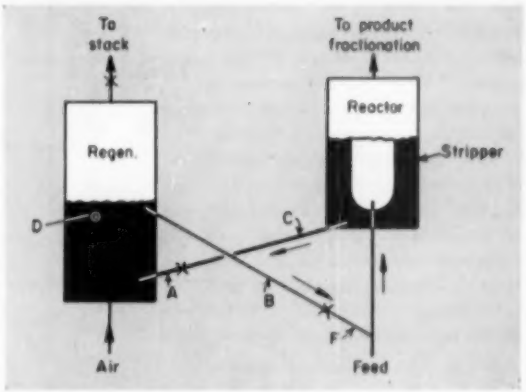
Hydrocarbon feed continuously enters the reactor, where it undergoes cracking at about 500° C over fluidized regenerated cracking catalyst. The crude product continuously exits overhead, after passage through cyclone separators (to drop out entrained catalyst particles), into the product fractionation system.

During the cracking process a considerable amount of "coke" (high-molecular-weight polymeric hydrocarbons), of the order of a few weight per cent, forms on the catalyst in the reactor section. This catalyst, referred to as "spent" catalyst, continuously spills over into the stripper, where it is contacted with steam at about 500° C. The stripping operation serves to vaporize some of the semivolatile polymeric material out of the pores of the spent catalyst, thereby decreasing the amount of coke to be burned off in the regenerator.

The stripped catalyst then moves downward in a dense-phase standpipe into the bottom part of the regenerator. In the regenerator the stripped catalyst is continuously contacted with air at an average temperature of about 600° C. In the fluidized dense phase of the regenerator the coke is burned off the catalyst to the point that regenerated catalyst leaving via two regenerated-catalyst standpipes drawing out of weirs at the top of the regenerator dense bed contains <1% carbon. The regenerated catalyst in these standpipes is continuously lifted by incoming feed vapors into the reactor, thus completing the catalyst circulation path.

The flue gas leaving the regenerator passes through a system of cyclones to drop out entrained catalyst and then out into the atmosphere through a stack. In spite of the cyclones, a large unit can lose 5–10 tons of catalyst per day out the stack. To maintain the catalyst activity approximately constant, catalyst is withdrawn periodically and fresh catalyst is added continuously. Catalyst circulation in the unit is continuous, and feed, steam, and air are fed into reactor, stripper, and regenerator, respectively.

The pressures throughout the unit are atmospheric to 2 atm gage, and the fluidized dense beds operate at densities of about 30 lbs/ft³. The entire unit can be 10–15 stories high, and the regenerator may be as much as 40 ft in diameter. All vessels and lines are of heavy-gauge steel with considerable thermal-lagging material on the outside.



CATALYTIC CRACKING UNIT. In regenerator mixing test injection is at A and sampling is at B, C, and D. In reactor test injection is at F and sampling is at B and C

out exceeding the weekly tolerance dose of 300 mr. The radiation levels involved during the injection operation have ranged from a few mr/hr up to a few hundred mr/hr, depending primarily on the isotope used and the number of millicuries involved. But the time required for the operation is only a few minutes, so the exposures are small. Shielding and long-handled tools are not necessary. Once the tagged catalyst is mixed uniformly with the total inventory of a commercial unit, the external radiation level is negligible—of the order of 0.01 mr/hr.

Ingestion. The accepted tolerance values for Ce^{144}-Pr^{144}, Cr^{51}, and Sc^{46} in the human body are 5, 390, and 6 μc, respectively (*3*). Thus, for the example of 1 gamma mc in 500 tons of catalyst, one could steadily maintain in his body all of the isotope in 1.0 ton, 15.5 tons, or 3.0 tons, respectively, of well-mixed inventory catalyst before reaching the body tolerance level! Clearly ingestion of catalyst after dilution in the unit is not a health problem.

Inhalation. The tolerance values for concentration in air are 7×10^{-9}, 8×10^{-6}, and 7×10^{-8} μc/cm³, respectively, for Ce^{144}, Cr^{51}, and Sc^{46}. In the catalyst mixing studies the extreme maximum loss rate of fines expected would be ~1% of the tagged catalyst during the first 24 hr. For the case of 1 gamma mc in a 500-ton inventory unit, operating with a regenerator stack effluent gas rate of 50,000 std ft³/min, the radioactive concentration of the effluent would amount to only 2×10^{-12} gamma μc/ml (at the effluent temperature) during this period of maximum concentration. This concentration is only 1/1,700 of the tolerance value for continuous breathing of Ce^{144}, 1/370,000 of the Cr^{51} tolerance value, and 1/42,000 of the Sc^{46} tolerance value. Atmospheric dilution rapidly lowers these concentrations further.

The minute amount of tagged catalyst that is lost from the stack during a mixing study is highly diluted with nonradioactive stack fines. Thus, for the 1-mc-in-500-ton case, with a loss rate of 1% per day, the specific activity of the stack fines would amount to only about 2×10^{-6} gamma μc/gm. One would have to ingest or inhale a few tons of such fines to reach a tolerance value in the body of Ce^{144}-Pr^{144} or Sc^{46}; for Cr^{51}, about 17 tons would be required. Thus it is clear that catalyst fines put into the air during such a catalyst mixing study do not constitute a radioactive health hazard of any sort.

Deactivation studies. In the catalyst-deactivation studies one uses a few tens of millicuries of tagged catalyst instead of only 1 mc. Furthermore, the stack loss rate of fresh catalyst is considerably higher than that of "equilibrium" catalyst. For example, in a 500-ton unit with a gas rate of 50,000 std ft³/min, if 20% of a 20-gamma-mc injection is lost during the first 24 hr, the effluent concentrations would be respectively, $\frac{1}{5}$, $\frac{1}{1,000}$, and $\frac{1}{100}$ of the continuous-breathing tolerance levels for Ce^{144}, Cr^{51}, and Sc^{46}. One would still have to ingest about 5, 85, or 17 lb of such fines, respectively, to reach, even momentarily, the body tolerance values for these isotopes. The stack

loss declines rapidly after the first day. Even during the period of maximum loss the dilution by nonradioactive catalyst fines is so great that the specific activity is only about 10^{-3} gamma μc/gm. Thus no radioactive health problem results from the loss of fines in the catalyst deactivation studies.

As a check on the above calculations a gas sampling survey was carried out for Shell by Tracerlab, Inc., during one of the catalyst-aging studies. Of the numerous samples collected, only six showed detectable amounts of Sc^{46}, and these ranged from 0.0006% to 0.029% of the tolerance level for Sc^{46}.

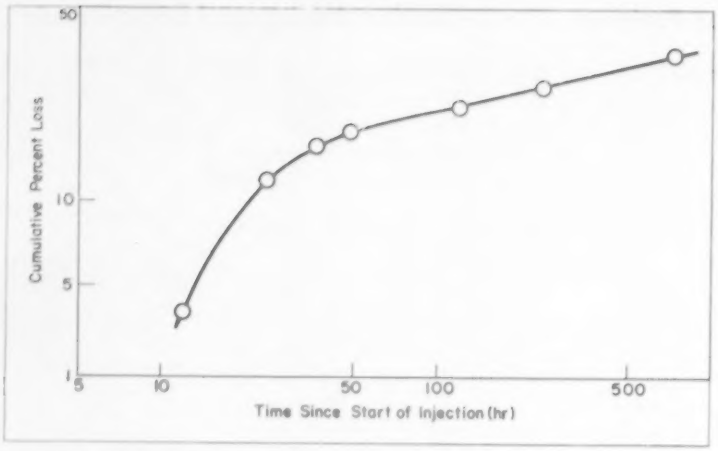


FIG. 3. Cumulative stack loss of fresh catalyst from regenerator

Catalyst Mixing Results

To illustrate the results obtainable in refinery studies, one of a series of mixing studies (*4*) will be described here.

Ten pounds of equilibrium catalyst tagged with 2 mc of Sc^{46} were injected in a 5-sec period into the spent catalyst standpipe just ahead of the regenerator (see box on p. 71). Continuous ½-min-duration samples were taken at each sampling point for the first 10 min after injection, followed by ½-min samples at 15, 20, 25, 30, and 60 min. Samples were taken at three different sampling ports: one of the regenerated-catalyst standpipes, a port near the top of the regenerator dense bed away from the drawoff weirs, and the spent-catalyst standpipe.

The tagged catalyst reached a maximum concentration at the regenerator dense bed sampling point in about 1 min (see Fig. 1). The tagged catalyst did not appear in the regenerated catalyst standpipe for 2 min after the injection and did not reach a maximum concentration until 5 min after injection. Similarly, tagged catalyst did not appear in the spent catalyst standpipe until about 5 min after injection. Thereafter the concentration slowly rose to the completely-mixed value for the entire unit.

Although the data show definite divergence from the idealized case, it is clear that the system at least approaches the complete-mixing model. The data can be interpreted (*4*) to give an accurate measure of the distribution of catalyst-residence times in the reactor-stripper and in the regenerator. When combined with information on the chemical kinetics of coke deposition in the reactor and coke burnoff in the regenerator, they provide insight into the distribution of catalyst activities in the unit. The data can be used to indicate changes in design or operation that will improve the performance of the unit, thus effecting substantial profit increases.

An incidental piece of information obtained from the radioactivity level of the catalyst after complete mixing throughout the unit is the total inventory. Knowing the amount of radioactivity injected and the final well-mixed counting rate, a simple isotope-dilution calculation gives a value of the inventory. Thus, in the example cited here, the value obtained by isotope dilution differed by only 0.1% from the refinery value, employing an entirely different, pressure-drop method. In all the studies to date the difference between the radioactivity value and the refinery value has been less than 2%, and usually less than 1%.

Figure 2 depicts the very rapid decrease of surface area of fresh catalyst as a function of time in one of the commercial units.

Similarly, Fig. 3 shows a typical stack loss rate of fresh catalyst in a commercial unit operating with cyclone separators but without Cottrell precipitators. For details see Ref. *5*.

* * *

The author is greatly indebted to the members of the chemical-engineering and petroleum-refining team with which he has worked as a member in planning and carrying out these studies.

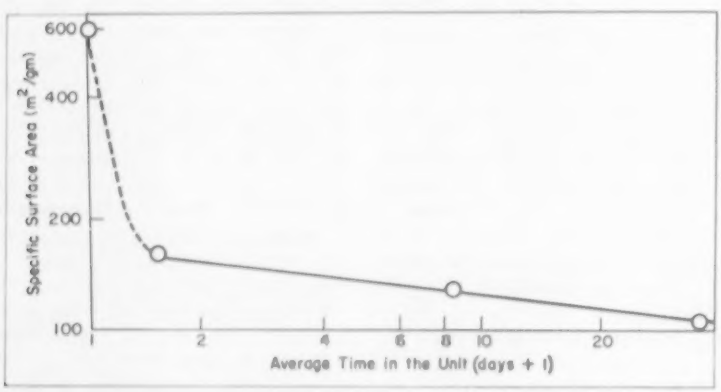


FIG. 2. Rate of decrease of catalyst surface area in a commercial fluid catalytic cracking unit

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Outlook for a Nuclear Merchant Fleet

The Maritime Administration, urging an immediate construction start, says we are now close to competitiveness; industry bids support this

THE ENCOURAGING industry response to the Maritime Administration's call for bids on building two atomic tankers, a short-range and a long-range project (NU, April '56, p. 17), has once again focused attention on the outlook for a nuclear-propelled merchant navy. Since there is no question as to the technical feasibility of an atomic commercial fleet, economic consideration will largely determine if, and how soon, such a fleet begins to call at the world's ports.

On this question of economic feasibility, there are two very sharply divided schools of thought in the Government. The Maritime Administration is highly optimistic as to the chances for an atomic tanker to be competitive in the immediate future. Not so optimistic is the Navy—at least as represented by Rear Admiral H. G. Rickover who, having almost single-handed forced through the construction of the *Nautilus*, is responsible for the fact that one nuclear-propelled vessel is actually sailing the seas today, and who is now supervising a naval construction program including 19 more atomic submarines plus an atomic cruiser, destroyer and aircraft carrier.

These opposing views are bluntly set out by Rickover and by J. J. McMullen, Maritime's chief of ship construction, in the McKinney report.* Maritime told the McKinney Panel last September that within five years cost factors might be reduced to competitive ranges for some types of vessels. Last month, after getting bids from four manufacturers on building immediately a "short-range" nuclear tanker using a modified *Nautilus*-type pressurized-water-reactor plant, Maritime was even more optimistic: it said such a ship would at worst be only 44% higher in cost than a conventionally-fueled tanker, at best would compete—and in either case would show a profit, with only the size of the profit margin in doubt. Two of the four proposals for a short-range tanker using a PWR-type plant (see table) would provide the reactor, first core loading and all main propulsion equipment for less than $10-million. In one of these proposed ships, the cost of hauling one ton of oil from the Persian Gulf to the East Coast works out to $11.15. This is only 44% more than the present average of $7.77 per ton with conventional tankers. In the second proposal of the four, this cost works out to only 20% more than the present cost.

Bidders on a Nuclear Tanker—

Phase 1, PWR-propelled, for 1959:

- **Babcock & Wilcox** (associated with DeLaval Steam Turbine Co. and Newport News Shipbuilding & Dry Dock Co.)
- **Foster Wheeler**
- **General Electric**
- **Ingalls Shipbuilding Corp.** (with Westinghouse Electric Corp.)

Phase 2, Gas-cycle, for 1961:

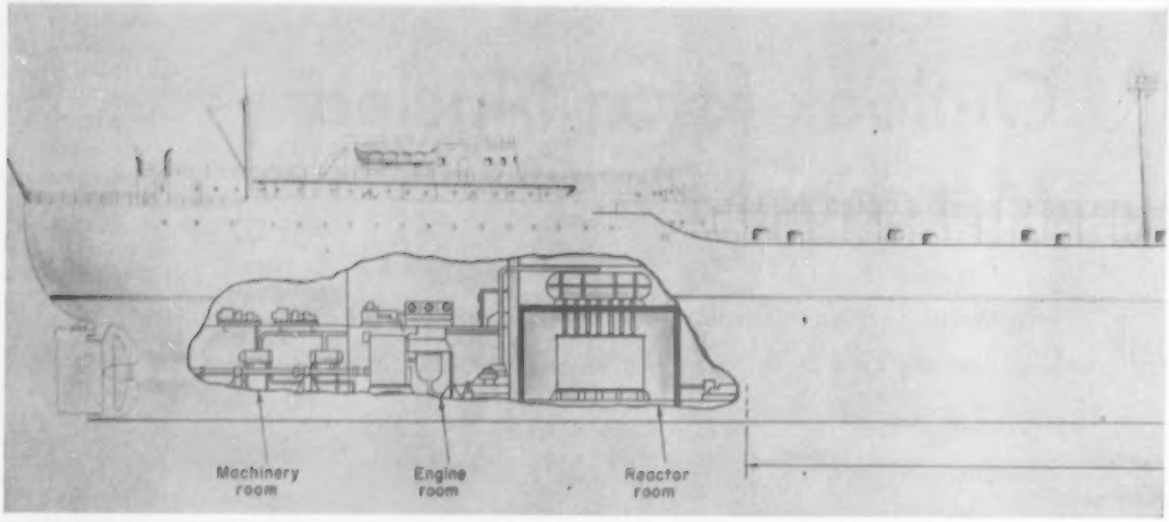
- **American Turbine Corp.** (with Ford Instrument Co., and George G. Sharpe, Inc.)
- **AMF Atomics** (with R. C. Morrell)
- **Atomics International (NAA)** (with J. J. Henry and Nordberg Mfg. Co.)
- **Ford Instrument Co.** (with Nordberg and H. Newton Whittlesey Inc.)
- **General Atomics** division of General Dynamics
- **General Electric**
- **General Motors** (Cleveland Diesel Engine division, with Internuclear Corp., Foster Wheeler, Farrell Birmingham, DeLaval Steam Turbine, Allis-Chalmers, and Bailey Motor Co.)
- **Nuclear Development Corp. of America**
- **Pacific Coast Nuclear Power Group** (Stanford Research Institute, American Radiator & Standard Sanitary Corp.; Todd Shipbuilding Co., and DeLaval Steam Turbine)

The Need

The question of a possible new type of merchant-ship propulsion is especially timely because the U. S. merchant marine is on the verge of block obsolescence. In the period between 1960 and 1965, about 93% of the 3,255 American merchant vessels of over 1,000 gross tons now serving will become 20 years old or older—obsolete. This will include 336 of 430 oceangoing tankers now in service. Any new type of equipment that has not been developed and proved to some extent within the next 5–6 years will not be introduced into our next generation of ships, which have a 20-year cyclic life.

Atomic replacements for all present U. S. oceangoing tankers over 15,000 tons deadweight, in the period 1960–65

* J. J. McMullen, "Propulsion of Commercial Ships by Nuclear Energy: A Survey Report," in Report of the Panel on the Impact of the Peaceful Uses of Atomic Energy, p. 215 (Government Printing Office, Washington, 1956); H. G. Rickover, *idem.*, p. 240.



NUCLEAR-POWERED TANKER—a conceptual drawing showing arrangement of propulsion machinery. Such a vessel could be used

on, would result in construction of 300 or more such vessels over a 20-year span. Taking Maritime's figure of $10-million per nuclear powerplant, this would mean an average annual business of $150-million. It would result in a shipboard installed atomic power capacity on the order of 15,000-Mw of heat by 1980, equivalent to roughly 7% of pessimistic estimates of central-station A-power in the U. S. in that year. Thus Maritime foresees the possibility that merchant marine needs could create a sizeable demand for the construction of atomic marine engines and for production and processing of fuel for them.

Oil-fired vs. Nuclear Ships

Nuclear-propelled ships, unlike conventional ones, have unlimited cruising range between refuelings (*Nautilus*' first fuel loading has driven her 26,000 miles in one year and is good for a second year). They need no combustion air supply or exhaust, and elimination of air-ducts and uptakes may provide an increase in space. Ship speed and turnaround time will not change substantially. The ratio of gross weight to cargo weight may decrease for high-density cargo such as oil, ore, or other bulk items, but not for low-density cargo. A small auxiliary oil-fired powerplant will be necessary for in-port electrical power generation during reactor refueling.

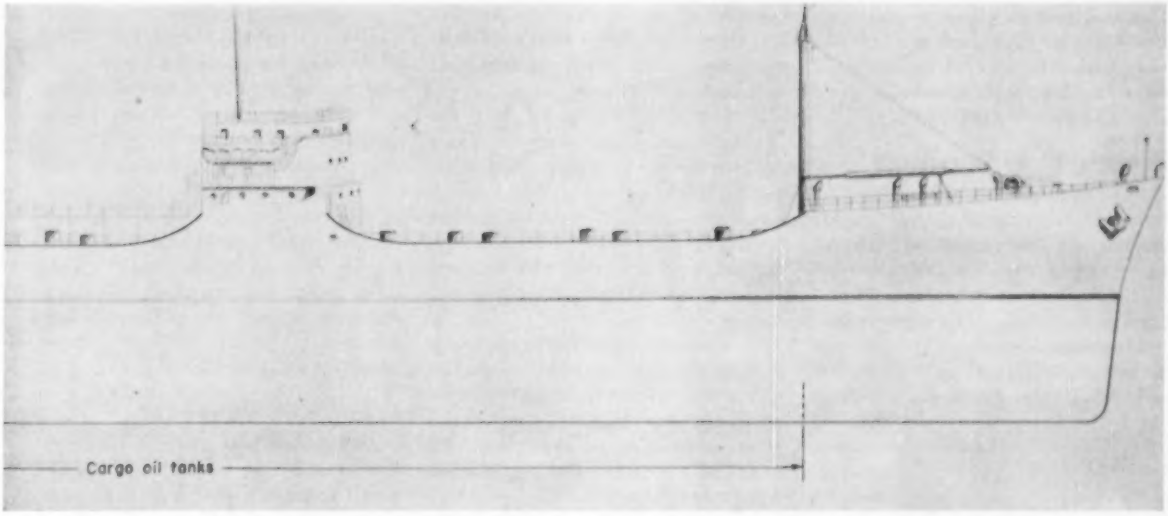
The fuel-oil costs in a high-powered conventional ship run into millions of dollars over the life of the vessel. The potentialities for reduction of costs of nuclear fuels offer great promise for economical operation of nuclear-powered ships, the Maritime Administration believes. Aside from costs, present-day fuel requirements for oil reduce the payload capacity by a significant percent, particularly in high-powered ships on long trade routes. The increase in payload capacity is a major and immediate source of benefit accruing from nuclear power. The greatest gain would of course be in the case of cargoes having high value per unit volume. In addition, the handling of fuel oil presents chronic problems in conventional ships. Long fuel-oil lines, pumps, heating equipment, bunker and settling tanks can all be eliminated, and with them troubles from corrosion, cleaning, and ballasting of bunker tanks. The problems of trim and stability that arise as fuel is consumed in an oil-fired ship would disappear. The problems of radioactive contamination that might arise should be no more severe, Maritime feels, than the problems now encountered when repairs are made in or near fuel-oil facilities.

McMullen also points out that application of atomic power to marine uses has great intrinsic advantages over land applications such as central-station power. In the latter, there is no possible increase in earning capacity through reduction of space and weight, whereas on shipboard such improvements are directly convertible to increased earning capacity. Furthermore, about 30% of the capital cost of land-based plants is not involved in marine applications. This includes ground clearing, excavation, buildings, and retention basins.

What Type of Ship?

A nuclear-propelled ship is expected to show the greatest economic advantage when competing with oil-fired vessels that operate under the following conditions: long trade routes; quick turnaround in port; dense and valuable cargo in unlimited supply; large deadweight capacity; relatively high power (minimum about 20,000 shaft horsepower); roundtrip bunker fuel taken on at same port as payload; payload carrier both ways; regularly-established home port on one end of voyage; arrangements such that advantages may be gained from elimination of uptakes and of smoke nuisance, and such that cargo may be utilized for secondary shielding.

This would indicate that nuclear power as it's known today is economically most feasible in tankers, oil carriers, and combination oil and ore carriers operating at relatively high speeds over long trade routes. Dry-cargo freighters, on the other hand, have slow port turnaround, their cargo is frequently limited and relatively light, and their size and speed is normally held down by limits on available cargo.



initially as a "peace ship" by temporary installation of an auditorium with projection booth and an exhibit hall in place of cargo tanks

• A tanker spends an average of 80%, and as high as 90%, of its time at sea. This would permit high utilization of nuclear fuel.

• The fuel oil consumed by a conventional tanker may amount to as much as 10% of the payload; elimination of this drain would mean an increased delivered payload that could result in added revenue of $1-million a year for a single 20,000-ton tanker.

• Since tankers usually dock at relatively unpopulated areas, require few shore personnel, offer the potential of offshore pumping, and have minimum time in port, the safety problem appears to be less in this case than for other types of nuclear-powered ships.

• Minimization of shielding may be possible by using oil cargo as secondary shielding.

• Steam load for pumping in port is about 40% of normal steam load; this high requirement for a tanker in port is conducive to efficient reactor utilization.

These are the reasons that led Maritime to conclude not only that the tanker is the type of merchant ship best fitted for the nuclear pioneer role, but further, that for a nuclear tanker "economic feasibility can be reached within a foreseeable future. . . . Cost factors might be reduced within a period of 5 years so that they are no more than the costs that will be experienced by conventional ships."

What's the Yardstick?

Crew wages, capital costs, and fuel and other operating costs constitute most of over-all expenses for a tanker; cargo handling costs, which run up to 50% for a dry-cargo freighter, are negligible. Of the total annual ship expense of a conventional tanker of 20,000 shp, fuel and capital charges amount to about 60%, of which capital is 35 to 40%. For such a tanker on, say, a Middle East run, present-day capital costs are about $450/shp. Maritime's studies show that by applying "vigorous programs of engineering to available technologies," a nuclear tanker engine could be built for about $850/shp. The studies also indicate that, discounting fuel costs, if capital costs for a nuclear tanker are kept within $10-million of such costs for a corresponding conventional tanker—and this can be realized, Maritime says—the nuclear ship may prove competitive.

Fuel costs are estimated by Maritime to range between $0.6-million and $4-million a year—the higher figure represents costs with the *Nautilus*-type reactor that already can be improved; the lower figure "can be approached within a reasonable period of time," Maritime says, if experience can be obtained promptly by building and operating nuclear ships. The agency points out that even if nuclear propulsion does not reduce fuel costs below those of conventional ships, it will make a great contribution in increasing considerably the earning capacity of tankers and other bulk carriers. Maritime further suggests that direct economic comparisons be obtained by building and operating a nuclear-propelled tanker otherwise identical with an existing conventionally-powered tanker.

Design Problems

There is no inherent difference between power reactors for merchant ships and those for central stations. But in the former, some peculiar problems arise—pitch and roll of ships, shock problems (although less than for combat ships), dockside core-reloading facilities, and power-level variations due to speed changes. However, health and safety considerations are more critical for central-station plants near populous areas. Weight and volume are reasonable; design can meet the effects on trim, stability and hull strength. Operational reliability is satisfactory and can be improved. Maintenance practices appear reasonable. Shielding and safety requirements can be met with no major changes in general arrangement. In a tanker, engines are installed aft: this eases shielding requirements as the reactor can be well separated from other shipboard work areas. Cargo oil could serve as all or part of a secondary shield under full load, and its place filled with salt water on the return trip.

Because reactor temperatures are still held down to 500–600° F by limitations of materials available today, turbine equipment must be designed to operate at saturated steam levels of 400–600 psi, not comparable to the superheated steam produced in modern

shipboard boilers. However, the gas-cooled reactor type, such as Maritime hopes to develop by 1961 for its "long-range" tanker, holds promise of going to much higher temperatures.

Applying Navy Experience

The *Nautilus* has established the technical feasibility of marine nuclear propulsion. And improved reactors are emerging from the Navy's $300-million research and development program on reactor plants for submarines.

Although *Nautilus*-type reactor plants are unlikely to be economic for commercial ships, experience with them can help in estimating and reducing costs of commercial nuclear propulsion. Eventually, reactors for commercial vessels will cost less than those for combat ships because of the latter's need for higher performance, more sensitive control, better shock resistance, and added restrictions on weight and space.

Dockside facilities for nuclear ships will be about the same as for conventional ships. But equipment for refueling spent fuel must be located in a shipyard with adequate lifting capacity, and remote-handling equipment for removing the spent elements and loading them into shielded casks for transportation to reprocessing plants. Such an installation would cost between $300,000 and $700,000; but, since it could be used for a number of vessels having similar reactors, cost estimates for reloading facilities "appear to be within reason," Maritime feels. Refueling would take 6–48 hours.

Difference of Opinion

Contrasting with Maritime's more optimistic figures (above) on nuclear vs. conventional costs, Admiral Rickover says a "replacement *Nautilus* powerplant" will cost about $18-million, and an oil-fired plant of equivalent horsepower about $2.5-million—one-seventh as much. With machinery making up 15–30% of total ship cost, a nuclear vessel would, by this estimate, cost 2–3 times as much as a conventional one. Comparing fuel costs, Rickover says that when fabrication, reprocessing, and handling are added to the value of the uranium consumed aboard the *Nautilus*, the cost is about 50 times that of fuel oil for equal shaft horsepower generation. This, he adds, is expected to be lowered to 15–20 times fuel-oil cost within five years, but fabrication and cladding-material costs will keep nuclear fuel from competing with fuel oil "for many years."

"At present," Rickover told the McKinney panel, "nuclear powerplants are more costly to design, build, operate, maintain and repair than conventional powerplants. With the present state of nuclear powerplant technology, it is not possible to predict the ultimate economic feasibility of nuclear-powered commercial ships.

"I recommend that reactors for commercial ships be realistically studied and evaluated for their economic aspects. When such a study and evaluation shows it to be worthwhile, the design of a reactor should be started. After a design has been obtained which promises economic advantages over conventional merchant-marine propulsion plants, experimental verification of the reactor design should be obtained. Not until these steps have been taken should construction of a nuclear-powered commercial vessel commence."

McMullen counters this view with: "It is believed that economic consideration can be determined and evaluated with accuracy only after construction and operation of several ships, which have paralleled the construction and operation of ships employing conventionally oil-fired steam-generating equipment. Consequently an immediate program of construction of nuclear-powered merchant ships is essential, as well as the undertaking of studies of those types of reactors which will permit raising energy levels comparable to the requirements of turbo-machinery now employed in merchant ships."

Curiously enough, Rickover himself, as recently as last May in testimony before the House Merchant Marine Committee, agreed with McMullen's position, which he himself was to oppose a few months later in his report to the McKinney Panel. On the earlier occasion, Rickover told the Merchant Marine Committee:*

"I think that atomic power has not yet reached the stage anywhere, with any size reactor, where it is economic. . . . I think, in approaching it for the merchant ship, you should not consider economics at the beginning. You should say, 'We have got to develop an atomic powerplant for a merchant ship. We will look around and see which offers the most promise for the future.' And you tackle that regardless of how bad it looks at the time. Have I made myself clear? . . . I think you had better go into it, and you will find out. It may cost you some money. And, since the country can afford this thing right now, at least you will know where you stand, and you will never know until you try it."

* Vessel Replacement Program: Hearings before the Committee on Merchant Marine and Fisheries, House of Representatives, 84th Congress First Session, pp. 252–253. (Government Printing Office, Washington, 1955.)

Influence on Manpower

And taking note of fears Rickover has expressed or implied in Congressional testimony that a nuclear merchant ship program might divert badly-needed engineers and technicians from the naval program, McMullen adds: "There have been some comments as to the possible influence on the naval program if the Maritime Administration is permitted to proceed with a program of nuclear reactor development. It is our considered opinion that, while there may be a slight impact at the very beginning, due to the increased effects of new talents and new facilities which would be brought into the overall program, the final effect can only be most beneficial to our national defense."

Hence Maritime's call for parallel short-range and long-range building programs starting at once:

"Construction and operation of merchant ships employing nuclear power with present-day technology; and—

"Establishment of long-range programs for employing new and more promising types of nuclear reactors in merchant ships meeting all of the requirements of commercial service vessels."

If this program is approved by the Administration and the Congress, nuclear power could become a significant source of power for commercial shipping within the next 10 or 15 years. The actual rate of development depends on (a) the relative competitive position of nuclear power as determined through experience, and (b) a basic Government decision as to requirements for atomic propulsion in the U. S. merchant fleet, maintained in part as a reserve for wartime emergencies.

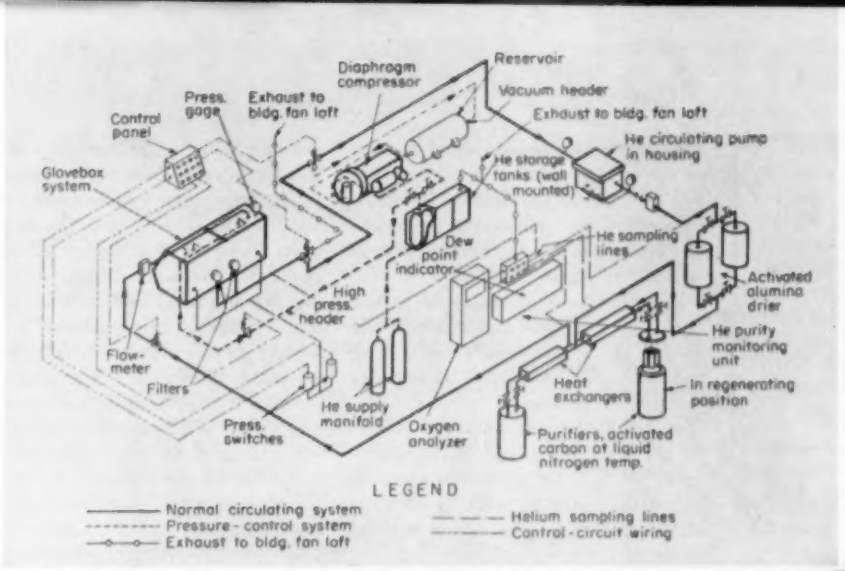
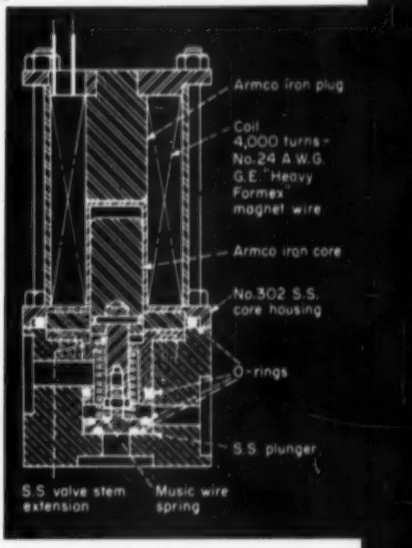


FIG. 1. Helium-circulating pressure-control system of the Research Laboratory

FIG. 2. Three-way d-c solenoid valve for Research Laboratory helium control system



Handling Alpha-Active Pyrophoric Materials

3—Glovebox-Atmosphere Control

Helium, because it is the easiest of available gases to regenerate, is used in the ANL glovebox systems. An efficient system requires careful design and component selection

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MOST GLOVEBOX SYSTEMS use once-through air ventilation. This approach presents problems in circulating, air conditioning, filtering, and pressure control. Extent of these problems depends on such factors as: quantity and rate of air moved, temperature and moisture content of supplied air, moisture content and pressure desired in the glovebox system, and the maximum permissible concentration of activity in air exhausted to the atmosphere. The more remote from populous areas, the less stringent are exhaust restrictions.

It has been argued that the normal method of removing exhaust air upward from contaminated systems is not satisfactory in that upward flow opposes the natural tendency of the heavy plutonium compounds to gravitate back to their point of origin (*1*). However, there is lack of agreement on the advantages of a downward flow of exhaust air (*2*).

Plutonium fires are minimized in such air systems by coolants with or without an inert gas supplied locally to operations, such as machining, where high temperatures are generated. But this is insufficient protection where pyrophoric materials are handled.

Many installations that use once-through air ventilation maintain individual tight gloveboxes; the atmospheres are purified by getters within the system or by recirculating the gas through an external purification train. Other such boxes rely on purging. But it is impractical to carry purging far enough to attain really pure atmospheres.

Large plutonium-handling systems have been constructed by AEC contractors to use relatively impure inert-gas atmospheres by a continual-dilution method. But they were unsuccessful because of the large use of gas necessary to keep up with the high in-leakage of air into the leaky systems. By exercising care in obtaining and maintaining a helium leak-tight system, the ANL Research Laboratory has succeeded in the continuous use of a pure helium atmosphere. The Fuel Fabrication Facility uses once-through air ventilation or a controlled pure helium atmosphere interchangeably in all or part of the system, depending on the work being done.

Selecting an Inert Gas

Nitrogen, argon, and helium have been suggested for gloveboxes.

Nitrogen offers some advantages, but

This is the last in a series of articles describing the glovebox systems of the ANL Plutonium Metallurgy Research Laboratory and Fuel Fabrication Facility. The previous parts were "What Is the Best Approach?" (March '56, p. 61) and "Design and Construction of Gloveboxes" (April '56, p. 65).

there appear to be conditions under which nitrogen reacts with plutonium—almost as vigorously as oxygen.

Argon is a comparatively dense gas and can be handled by fans and blowers designed for air. However, purification is somewhat of a problem. Adsorptive systems do not perform well with argon since the argon is adsorbed nearly as readily as is oxygen and nitrogen. One recommended method is to react the oxygen with an excess of hydrogen to form moisture, which is removed by an adsorption method, and then to remove the excess hydrogen and other gaseous impurities by liquifying and rectifying. This appears to be a costly procedure. Chemical purification does not appear attractive.

Helium's low density makes it difficult to circulate by means of fans or centrifugal blowers. Its high diffusivity makes it somewhat more difficult to contain than the heavier gases. The high ratio of constant-pressure to constant-volume heat capacity, $K = 1.66$ (instead of $\sim$1.4 as for most gases), means that its temperature increases much more in compression than do the other gases (argon excepted), and the negative Joule-Thompson coefficient means that it does not cool on free expansion through an orifice or expansion valve. Advantages of helium are its high heat capacity and its high thermal conductivity. The fact that it can be pumped through filters and pipes with relatively small pressure drop partially offsets the difficulty of pumping. But the principle advantage is that there are feasible regenerative methods of purifying helium with good yield and high clean-up factor. This was our main reason for choosing helium.

Helium Purification

The methods of purification of helium investigated at ANL include:

1. Chemical purification by reacting impurities with various liquid or solid gettering materials.

2. Cryostatic purification involving condensing out the heavier molecules by cooling the gas to the temperature of liquid nitrogen.

3. Adsorption on activated carbon at or near the liquid-nitrogen temperature and at atmospheric pressure with regeneration of the carbon by warming to room temperature.

4. Adsorption on activated carbon at normal refrigeration temperatures ($-20°$ F to $-40°$ F) and at elevated pressures (6–40 atm) with regeneration of the carbon by evacuation without changing the temperature.

The major objection to gettering is that the chemical reaction is irreversible so that sizable quantities of radioactively contaminated, chemically active materials must be replaced and disposed of. Gettering materials considered include uranium, titanium, zirconium, calcium, lithium, sodium, and sodium-potassium eutectic alloy. Most of them require elevated temperatures. Such problems as dusting of the solid metals and difficulties of containment at the required high temperatures made gas bubbling through the molten low-melting metals appear more attractive. Although molten lithium removes impurities quite efficiently, above the melting point it and its oxide and nitride are so corrosive that no reasonable container material was found. The sodium-potassium alloy was easy to contain but does not remove nitrogen and hydrogen. A difficult-to-remove aerosol was formed on bubbling helium through the liquid alloy.

The cryostatic purification method is used extensively in helium-producing plants where it is supplemented by adsorption on activated carbon at liquid-nitrogen temperatures (*3*). The adsorption method has been used successfully for over 1½ years in the Research Laboratory. With the slow gas flow used, almost any desired purity can be achieved. However, an unfailing supply of liquid nitrogen must be available; although this is not a serious problem at the <100 liters/day used in the Research Laboratory, a nitrogen-producing plant would be needed for a much larger scale. Also, the regeneration cycle is slow and wasteful of liquid nitrogen since it involves warming the activated carbon to or above room temperature to release the adsorbed gases. Also, means must be provided to remove water from the parts of the system that are cooled by the liquid nitrogen even though an efficient drier is used preceding the activated carbon system. In the Research Laboratory, activated alumina lowers the dewpoint of the helium to at least $-80°$ F. Accumulation as ice in the colder parts of the system of the moisture that does get through the drier results in increased pressure drop and an eventual need to remove the moisture.

The much larger size of the Fuel Fabrication Facility makes the purification problems more difficult. The present design is in the direction of adsorption on carbon at elevated pressures and at normal refrigeration temperatures. Field and Wells recommend adsorption on activated carbon at $\sim$150 psig and -20 to $-40°$ F with Freon refrigeration (*4*).

Obvious advantages of the method are: (a) at 10–11 atm the partial pressures of both moisture and gaseous impurities are increased to the point where comparatively small equipment can be used, (b) the activated carbon towers operate at a temperature above the dewpoint of the drier so that there is no frost problem, (c) regeneration of the charcoal towers is by evacuation at the constant temperature range of -20 to $-40°$ F so that a rapid 30-min-adsorption, 30-min-regeneration cycle is possible. This greatly increases the effectiveness of the process and permits use of small adsorption equipment.

Disadvantages of the process are: (a) a large amount of mechanical equipment is involved, (b) a high-pressure piping system must be helium tight, (c) a large quantity of cooling water is needed for the refrigeration unit and compressors.

RESEARCH LABORATORY SYSTEM

The helium-circulating and pressure-control system used in the Research Laboratory is shown in Fig. 1. The two gloveboxes shown connected with parallel plumbing represent the entire system of 18 interconnecting gloveboxes with a total volume of $\sim$280 ft^3.

Helium Circulation

The helium leaves each glovebox

Transfer Techniques

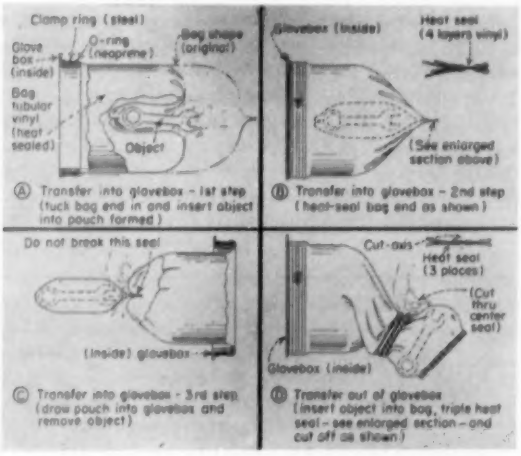
Transfers into, and especially out of, the glovebox system are potential sources of contamination.

Where activity levels are low, some systems permit transfers through an air lock, frequently by putting contaminated items in a clean container.

Transfer compartments have been designed that can be sealed tight while attached to the system and then quickly disconnected by a breachlock. Such devices are cumbersome, and complete freedom from contamination is not always achieved in the region where the compartment attaches to the system.

Where high-intensity alpha emitters are being handled, and especially metal powders, the air-lock-transfer method can be used only when well planned, and then only for introductions. In the Fuel Fabrication Facility, several air locks in the form of tight gloveboxes in series, separated by tight-fitting doors, are used for introductions (NU, March '56, p. 62, Fig. 2). Thus the probability is greater of keeping the glovebox that opens to the room free of contamination.

In the glove-change technique (NU, April '56, p. 69), an object can be placed between the old and the new gloves and exposed to the inside of the system when the old glove is removed from the port. Such a method introduces air with the object being transferred—this must be kept in mind if an inert atmosphere must be protected.



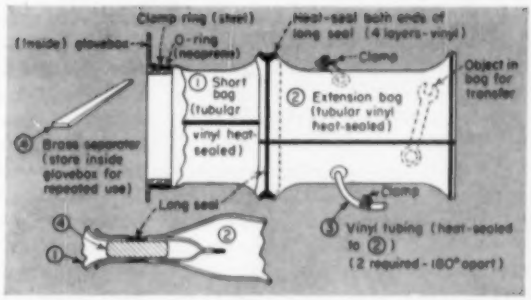
Ⓐ Transfer into glovebox – 1st step (tuck bag end in and insert object into pouch formed)

Ⓑ Transfer into glovebox – 2nd step (heat-seal bag end as shown)

Ⓒ Transfer into glovebox – 3rd step (draw pouch into glovebox and remove object)

Ⓓ Transfer out of glovebox (insert object into bag, triple heat seal – see enlarged section – and cut off as shown)

PLASTIC-POUCH TECHNIQUE for transferring objects into or out of Research Laboratory glovebox system


Clamp ring (steel)
Heat-seal both ends of long seal (4 layers-vinyl)
(inside) glovebox
O-ring (neoprene)
Clamp
Object in bag for transfer
① Short bag (tubular vinyl heat-sealed)
② Extension bag (tubular vinyl heat-sealed)
④ Brass separator (store inside glovebox for repeated use)
Long seal
Clamp
③ Vinyl tubing (heat-sealed to ②) (2 required - 180° apart)

EXTENSION PROCEDURE for pouch too short for further use; alternative is to replace pouch similarly to glove-change technique. Objects can be put into system during pouch extension or change. Lower left is enlarged cross section of seal

Plastic-pouch transfer techniques have permitted transfers into and out of the highly active Research Laboratory boxes without spreading activity. At ANL we have used 20- and 12-mil-thick vinyl plastic made into pouches with a neoprene O-ring sealed into the open end. Others have used such plastics as cellophane and polyethylene. The vinyl is relatively easy to seal to itself by standard dielectric sealing methods. For pouches up to 15 in. in diameter, the largest used in the Research Laboratory, a 2-kw dielectric-sealing power unit has proved adequate. For the Fuel Fabrication Facility, with pouches up to 48 in. in diameter, a 4½ kw power unit is used.

The pouches (15 in. and 9½ in. in diameter) are sealed to the Research Laboratory glovebox system (NU, March '56, p. 62, Fig. 1) by the same clamping system that has been described for gloves (NU, April '56, p. 69). A vacuum lock is located between the inert-atmosphere boxes and an air box. Pouches are attached to the vacuum lock and the air box so that objects introduced through either pouch can be freed of air and moisture by evacuation before they are introduced.

A gastight door covers the pouch port both to prevent damage to the pouch and to minimize air and moisture diffusion into the inert-gas system.

These transfer methods will also be used in the Fuel Fabrication Facility. A modification is the 48-in.-diameter transfer port that has been designed into the bottom of a glovebox with provisions to facilitate removing large heavy objects. The extended pouch in this case is completely housed by a ventilated hood to ensure safety during the dielectric sealing operation.

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through an efficient fiber filter at about 1 ft³/min (20 ft³/min for the system), is pumped by graphite-vane rotary pumps through a closed loop of silver-soldered copper piping to a drier, heat exchanger, and purifier, then back to the glovebox system.

Pressure Control

The pressure is controlled at between −0.5 and −1.5 in. of water by a superimposed pressure-vacuum system. If the pressure exceeds −0.5 in., a sensitive pressure switch actuates a solenoid valve connected to a vacuum chamber that rapidly evacuates enough helium from the system to return the pressure to the proper range. If the pressure falls below −1.5 in., a similar system introduces helium from a pressure chamber. An automatically operated stainless-steel-diaphragm compressor transfers to the pressure chamber the helium that is taken into the vacuum chamber, thereby conserving helium.

Emergency Ventilation

The emergency exhaust system consists of a line to the building fan loft, which is maintained at −9 in. of water by a booster blower having its own standby power generator.

The system automatically calls on

this emergency exhaust if the pressure remains too long above −0.5 in. of water (or any other desired limit), if the oxygen content in the helium increases beyond a predetermined level, or if the power supply is interrupted.

Whenever the emergency exhaust is called upon, groups of gloveboxes are automatically isolated from each other so that the defective group cannot adulterate the balance of the system. The defective group can be valved off manually so that normal operation of the rest of the system can be continued.

Purification System

Purification is accomplished by an adsorption system consisting of activated alumina driers followed by activated carbon at liquid-nitrogen temperatures (*5*). The system efficiently removes water, oxygen, nitrogen, hydrogen, and other impurities including volatile organics.

In normal operation of the glovebox system, the main sources of impurities are diffusion through the large surface area of the 60 gloves and entrainment with items that are insufficiently outgassed prior to transfer into the system. Aside from using glove-port covers, no appreciable effort has yet been attempted to minimize these sources of impurities. Nevertheless, the impurities in the glovebox atmosphere can be held with ease to less oxygen than is normally found in commercial tank helium (10–20 ppm) and less than −50° F dew point (~100 ppm water). Actually, the concentration of oxygen and moisture in the helium leaving the purifier is less than a few ppm.

The drier is one that is commercially available but has been reworked for tightness having two columns of alumina in parallel to permit continuous operation—one can be regenerated while the other is adsorbing. Regeneration is accomplished by internal recirculation of heated helium through the alumina and then a condenser.

The helium is then cooled in a heat exchanger by flow countercurrent to the helium that is returning to the gloveboxes from the liquid-nitrogen-cooled purifier. This effects a considerable savings in liquid nitrogen and warms the helium returning to the system, thereby preventing sweating of the plumbing and box walls. The heat exchangers are very efficient standard commercial units that are made of corrugated aluminum. They are insulated with Santocel (a silica aerogel).

The activated carbon (about 20 mesh) of the purifiers is contained in 6-in.-diameter by 2-ft-long aluminum cylinders. Four of these are immersed in liquid nitrogen contained in large vacuum Dewars made of steel about 18 in. i.d. × 4 ft long. The precooled helium first passes through aluminum tubes immersed in liquid nitrogen so as to cool the helium to −195° C, and then passes downward through two of the carbon columns in parallel, then up again through aluminum tubing for another downward pass through the other two carbon columns. Thus the helium sees a long carbon path without suffering appreciable pressure drop.

The liquid-nitrogen level is maintained automatically by oxygen-vapor thermometers (*6*) in the Dewar, which operate a solenoid valve (*7*) to permit flow of liquid nitrogen from a 1,000-liter storage vessel.

Two such purifiers are used in parallel to permit continuous operation. Each has its own heat exchanger. To regenerate the carbon, the Dewar is dropped away from the stationary carbon containers permitting them to warm up to room temperature. The liberated gas is evacuated through high-efficiency CWS filters to the exhaust-fan loft. Water can be driven off by heating the carbon above 100° C.

Air Ventilation

Some of the Research Laboratory functions necessitate aqueous techniques, e.g., electrolytic polishing and etching and solution of samples from which aliquots can be taken for chemical analysis. Thus, four gloveboxes of the system can use air or helium. Also, equipment outside the system that might be a source of contamination is housed in tight gloveboxes and provided with air ventilation.

FABRICATION FACILITY SYSTEM

Ventilation for the Fuel Fabrication Facility consists of: (a) a once-through filtered air ventilation system, (b) an automatic standby emergency air ventilation system, (c) a recirculating helium system using regenerative-type adsorption purifiers with provisions to replace the air ventilation in any part or all of the facility, (d) a once-through filtered air system to ventilate the contamination risk equipment housed outside the glovebox system. The gloveboxes in which the unclad alpha-radioactive materials are worked is operated at a negative pressure of −0.6 to −0.8 in. of water, whether operated with air or with helium atmosphere.

It is hoped to increase the efficiency of this process by using the peculiar thermodynamic characteristics of helium to regenerate the drying towers and to act as its own refrigerant. Re-

High-Efficiency Dry Filters (*9*)

Medium	*Test aerosol*	*Air velocity (ft/min)*	*Resistance (in. of water)*	*Efficiency (%)*
Cellulose-asbestos paper CC-6	Methylene blue	4	1.0	99.9871 (discoloration)
	DOP	5.25	1.0	>99.9 (penetrometer)
AEC	Normal air	5.25	0.8	99.98 (count)
Sand*	Cell ventilation gases	3–5	4.5–5.5	99.5–99.8 (radioactivity)
Composite glass wool	Process off gases	20	4.0	99.9+ (radioactivity)
Compressed glass fiber†	Normal air	5.25	0.69	99.997 (count)
Resin wool‡	Normal air	14	0.3	99.6 (discoloration)

* 69 in. deep; graded sizes from 2¼ in. to 50 mesh.
† 0.02 in. thick; 50% 1.3 μ and 50% 3 μ fibers.
‡ ½ in. thick.

generation will be accomplished by evacuation while the activated carbon is still under refrigeration.

Filtered-Air Ventilation

The glovebox-air-ventilation system draws a maximum of 120 ft³/min of room air through the damper filters at the outer ends of each glovebox line. The pressure is controlled by outlet and inlet dampers.

The filtered air is distributed through the hollow cavities in the lower longitudinal extrusion and introduced into the glovebox modules through adjacent slots. The air is withdrawn from the glovebox through similar slots in the upper longitudinal extrusions and carried through the upper extrusion cavities and the duct pipe to the outlet filter housing above the conveyor enclosure.

After passing through high-efficiency filters, the air passes a rubber-lined butterfly valve that serves the dual function of providing a positive shut-off of the air system when the gloveboxes are operated with inert gas and as a balancing damper. It then passes through a short run of pipe to the main exhaust ventilation header, which is maintained at a static pressure of about −2.0 in. of water. The exhaust air then passes through final AEC high-efficiency filters and a vortex damper-controlled exhauster, which discharges to a common plenum and the 100-ft stack to the outside of the facility building.

Emergency Ventilation

The emergency system consists of a purge blower, prefilter, and final filter system installed in the fan loft, which operate continuously at essentially no flow. The system is sized at 3,000 ft³/min.

The purge of ventilation equipment at the gloveboxes includes a gas-tight, rubber-lined, 10-in.-diameter butterfly valve operated by a pilot-positioned damper motor. This in turn is controlled by a pneumatically operated static pressure controller with a control tip in the gloveboxes and a reference tip to the room. This controller is set to control the valve to maintain approximately 400-ft/min velocity head between the outside and the inside of the gloveboxes, but, when the gloveboxes are operating with −0.6 to −0.8 in. of water, to close fully and seal.

Separate but similar purge systems are attached to the alpha-radioactive-work gloveboxes and to the clad-work gloveboxes.

Subhood Ventilation

The room ventilation is a once-through system that takes air from the outside and filters and cools it to reduce the moisture to below 50% relative humidity at 80° F. It then reheats and discharges the air into the room. The excess building ventilation not required for ventilating the primary gloveboxes is carried through the paneled spaces beneath the boxes to cool and ventilate the contamination-risk equipment housed in these spaces. A slight negative pressure is maintained in the spaces by introducing air to the enclosures through glass-wool filters. The air is prefiltered through similar glass-wool filters before exhausting to the general building exhaust system. The final filters of the general building exhaust system are high-efficiency filters.

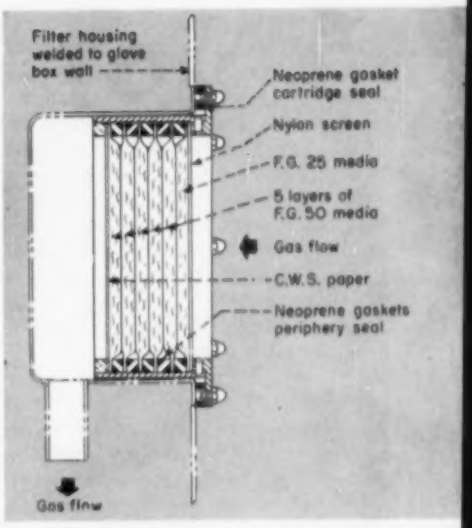

FIG. 3. Filter assembly for Research Laboratory helium-circulating system. Assembly uses American Air Filter Co. fiberglass prefilter and Chemical Warfare Service (CWS) asbestos paper filter

AUXILIARY EQUIPMENT

Several types of ventilation-system equipment require more detailed discussion.

He Pumps, Compressors

Helium-gas pumping presents several problems not encountered with other gases: (a) Since helium density is about one-seventh that of air, a centrifugal blower produces slightly less than one-seventh the pressure head as when used with air, (b) the isentropic temperature rise with compression is greater than that of the more common gases, (c) positive-pressure blowers must "seal" much more tightly (have small clearances) to prevent back slippage. For these reasons it has been difficult to get the manufacturers of either centrifugal or positive-displacement pumps to recommend their products for helium pumping.

For small systems, positive-displacement pumps have been used satisfactorily, including the rotary-vane, piston, and diaphragm types. The Research Laboratory uses standard inexpensive rotary-graphite-vane pumps. These pumps require no lubrication. Unfortunately, their service life is short (2–6 months). Therefore, they must be designed in such a way as to permit easy replacement.

The pumps are not helium tight to the outside and, thus, must be housed. It is necessary to minimize pulsation or shock and pressure differential and to provide adequate cooling and filtering to prevent loose particles from entering the pump.

For very slow flows but for high pressure differentials across the pump, diaphragm pumps have been used very successfully. For about a year the Research Laboratory has used such a pump with a 14-in. stainless-steel diaphragm to compress helium from the vacuum chamber and store it in the pressure chamber. Spherical valves and valve seats are made of two types of Stellite to insure long life with minimum wear, sticking, and friction.

For large systems, a multistage turbine-type compressor appears to be the answer. The circulating blowers for the Fuel Fabrication Facility are seven-stage turbocompressors, which, at 3,500 rpm, handle 1,000 ft³/min each with a pressure head of ~0.65 psi. Two of these units are used with an aftercooler after each compressor. Cross-over connections and valves are provided so that: (a) one blower can be used while the other stands by, (b) both blowers can be used in paral-

lel to move up to 2,000 ft³/min of helium at 0.65 psi, or (c) the two blowers can be used in series with the aftercooler of the first becoming the intercooler between them. When used in this manner, the compressors have been calculated to produce 1.15-psi pressure head at 1,000 ft³/min. One desirable characteristic of this type of blower is that the pressure curve is nearly flat from the surge point to the rated capacity. Surging will occur at ~40% rated flow.

Valves

Manual valves that meet vacuum-system requirements are normally satisfactory in the type of helium-circulation system under consideration. A standard, commercially available, bellows-sealed valve with an O-ring seat and a port and stroke equal to the diameter of the tubing to which it is connected is used extensively in the Research Laboratory helium-circulation system.

A number of valves were designed and built to meet the need for two- and three-way solenoid valves having long life, minimum maintenance, and low flow resistance. They were designed to operate on 28 volts, d-c. As shown in Fig. 2, the solenoid plunger is housed in an O-ring-sealed stainless-steel container, and the energizing coil is on the outside of the housing. These valves have been cycled over 100,000 times without failure.

Filters

Filters are used in high-level alpha systems to minimize the spread of contamination through the system as well as to reduce, to a safe level, the escape of contamination in exhaust gases.

In closed systems such as the Research Laboratory, very little gas is exhausted to the atmosphere. Filters are used mainly to protect parts of the system from contamination, thereby making maintenance easier. For once-through air-ventilation systems, the need for filtering increases directly as the amount of exhaust gases increases.

Dry-filtration systems are the most effective where plutonium is involved. Wet filtration and electrostatic precipitation have limitations. The properties of gas-filtering media have been the object of considerable study (*8*). The table summarizes the performance of some high-efficiency dry filters. Since these data were compiled, an all-glass-fiber fireproof filter has been developed with performance comparable to or better than the cellulose-asbestos paper filters (*10*).

Effective filters gradually plug and their resistance to gas flow increases. Even though this improves their efficiency, excessive pressure drop eventually requires replacement. To replace a filter cartridge without allowing appreciable contamination to enter the filter housing and attached plumbing requires care and forethought. Roughing pre-filters is recommended to extend filter life and thereby reduce the number of changes required.

The extremely small particle size anticipated for plutonium powder-metallurgy work makes imperative the selection of the most efficient filters available. For very low gas flow rates, as in our closed laboratory system where recirculation of the helium is only for the purpose of purification, pressure drop is a minor problem and the filter assembly shown in Fig. 3 has been very successful. The small area of these filters, only 0.1 ft², presents no pressure-drop problem for our normal operation. However, it does limit the amount of gas that can be evacuated from the system in case of an emergency—such as a leak in the system. To handle such emergencies, filters of larger area should be used if space permits.

The emphasis on minimizing dust formation in the Research Laboratory and the slow gas flow has extended filter life. No plugging has occurred in any of the filters after over 1½ years of service.

To ventilate the Fuel Fabrication Facility system, air is drawn in through AEC fireproof-medium filters located in filter housings at the outer end of each glovebox line. These filters are sealed to the filter housings with pressure-sensitive vinyl tape and covered by a sheet-metal protective cover with a throttling damper. The exhaust is discharged to the common exhaust duct through a 12 × 12 × 6 in. high-efficiency fireproof filter similar to the inlet filter except that it is supplied with a closed-cell neoprene gasket to seal it to the outer filter housing. After the air passes the hood exhaust filter, it is drawn through an exhaust header, a parallel bank of 24 × 24 × 12 in. AEC high-efficiency filters, and a fan, and discharged through a 100-ft-high stack to the outside of the building. Filtration of the emergency air-exhaust system is through two banks of 24 × 24 × 12 in. filters in series. The first of these filters is changed by the vinyl pouch change method.

Purity Indicators

Water and oxygen are the impurities of greatest concern in an inert-gas plutonium system. The amount of these impurities is a check on the purification-system efficiency, which indicates when the purifier requires regeneration.

Automatic monitoring devices are available commercially that detect extremely low levels of both oxygen and water in the inert gas. In the Research Laboratory an oxygen monitor, based on the large positive magnetic susceptibility of oxygen and sensitive to 2-ppm oxygen, continuously records the oxygen content; it switches the system to an emergency exhaust and simultaneously sounds an alarm when the oxygen content rises above a predetermined level. Another available device is based upon reacting the oxygen with an excess of hydrogen and then measuring the amount of moisture that is formed. This device can also measure the hydrogen content. It loses sensitivity and accuracy if organic vapors are present.

Experience indicates that the peculiar thermodynamic characteristics of helium, its negative Joule-Thompson effect, and its high heat of compression, make difficult the application of moisture analyzers based on measuring dewpoint.

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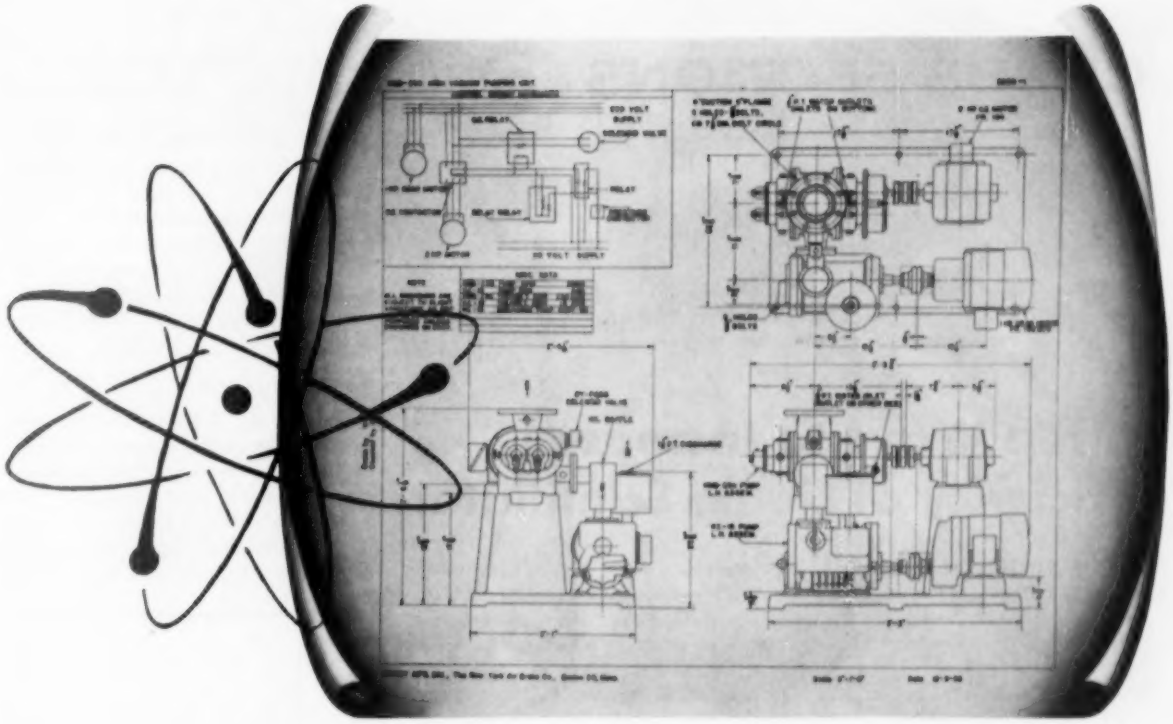

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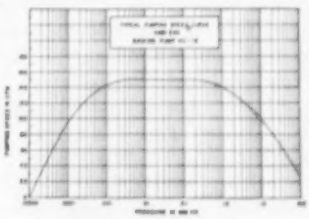

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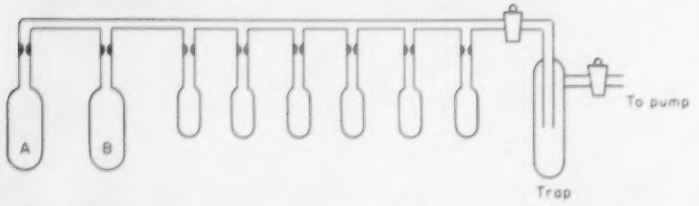

FIG. 1. Glass vacuum distillation system for making gas-free scintillation solution

Three Ways to Increase Efficiency of Liquid Scintillators

By C. A. ZIEGLER, H. H. SELIGER, and I. JAFFE
National Bureau of Standards
U. S. Department of Commerce
Washington, D. C.

The liquid scintillation-counting technique is of value for measuring low-energy beta emitters since it eliminates the usual self-absorption of solid sources in 4π beta counting.

In applying this method it is important to obtain maximum scintillator light output. Thus, several means of increasing the effective light output of *p*-terphenyl in xylene and 2,5-diphenyloxazole in xylene scintillating solutions have been investigated: (a) removal of oxygen and other gases present, (b) addition of the wavelength shifter α-naphthylphenyloxazole, and (c) reduction in temperature. The effects of (a) and (b) are markedly dependent upon solute concentration.

Experimental results for effects (a) and (b) (*1–6*) are not in close agreement. The effect of temperature (*7*) on gas-free liquid scintillators has not hitherto been investigated. Previous workers have used an oxygen-removal procedure that consisted of bubbling nitrogen or argon through an air-saturated solution and measuring the increase in the light output while bubbling, or immediately subsequent to bubbling (*1–4*). In the present experiments a system was designed to eliminate oxygen as well as other gases.

Experimental Procedure

Figure 1 shows the system used for preparing gas-free solutions.

To avoid any possible effects due to stopcock grease, the solvent-transfer portion of the vacuum system was kept free of stopcocks. Appropriate quantities of solute in powdered form were weighed into cylindrical Pyrex ampoules that then were flame-sealed onto the vacuum manifold. The solvent, xylene, was placed in flask A, frozen in liquid nitrogen, and flame-sealed to the vacuum system. By vacuum distillation a portion of the solvent was condensed into flask B. Flask A was then removed from the system. Appropriate amounts of solvent from flask B were then condensed into the Pyrex ampoules using liquid nitrogen. The ampoules were flame-sealed while still under vacuum and removed from the system. These degassed solutions then were compared, in a reproducible geometry, with similar solutions that were air-saturated.

The ampoules were placed in a uniform, Ba^{137} gamma-ray field. The scintillations produced in the liquid by Compton electrons were observed with a DuMont-6292 photomultiplier tube. No effort was made to insure optimum light collection.

Measured pulse-height distribution was exponential with no photopeaks or Compton edges. The integral of this pulse-height-distribution curve can be taken as an index of the total light output (*8*). To confirm this, curves of light output vs. concentration were obtained for air-saturated solutions of *p*-terphenyl in xylene and 2,5-diphenyloxazole in xylene at room temperature using integral pulse counting as an index of light output. These curves are identical to those obtained by measuring integrated current output of the phototube as described elsewhere (*3*).

More directly, a separate experiment was performed in which the relative increase in light output due to degassing and lowering the temperature was measured using the peak position of the pulse-height distribution from an internal Po^{210} alpha-particle source as the true index of light output. The results agreed with those obtained by measuring integral pulse counting rates in the Ba^{137} gamma-ray field.

Results

Figure 2 shows the percent increase in light output of degassed over air-saturated solutions at 28 °C as functions of solute concentration. The relative increase due to gas removal is strongly dependent upon solute concentration. Furthermore, the increase

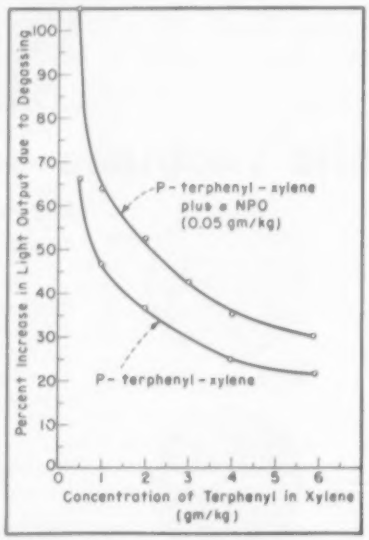

FIG. 2. Effect at 28° C on light output of degassing as function of concentration for p-terphenyl in xylene solutions with and without α-naphthylphenyloxazole. Circle diameters indicate precision

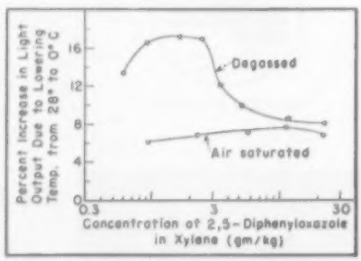

FIG. 3. Effect on light output of lowering temperature of degassed and air-saturated solutions of 2,5-diphenyloxazole in xylene. Circle diameters indicate precision of measurements

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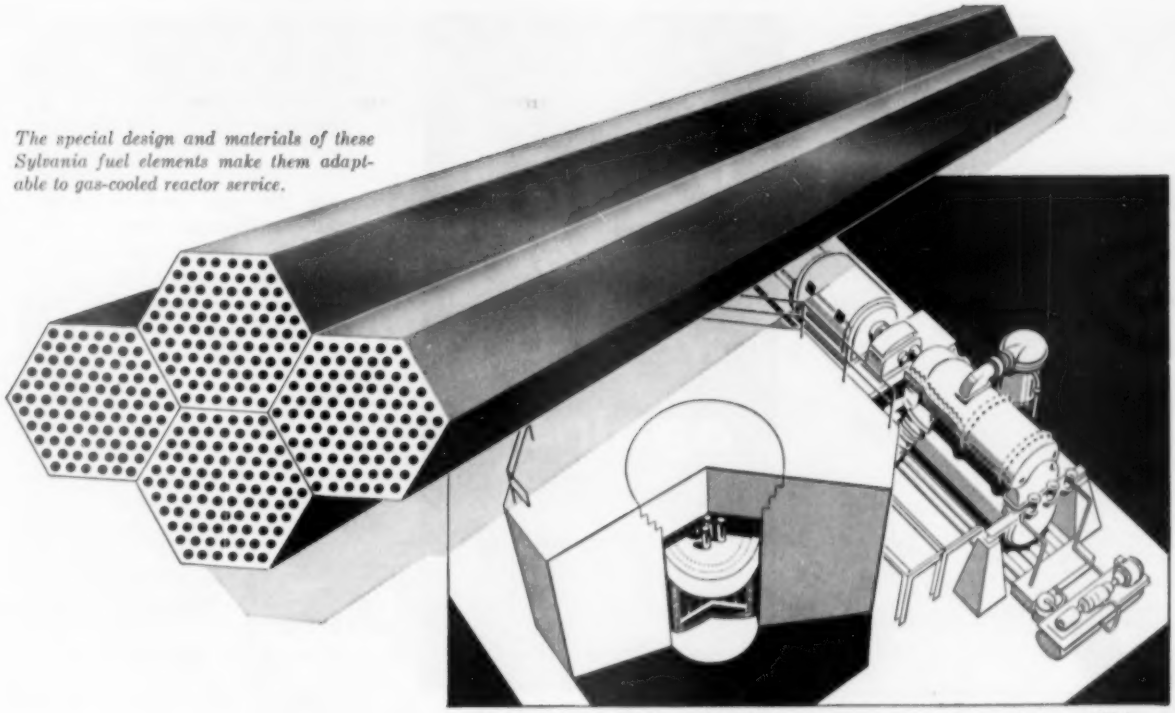

A typical closed cycle gas-cooled reactor power plant system design, utilizing a gas turbine translation unit. Drawing courtesy of American Turbine Corporation and Ford Instrument Company.

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due to adding α-NPO is seen to be a function of solute concentration.

Figure 3 shows the percentage increase in light-output for a decrease in the temperature from 28° C to 0° C as a function of solute concentration for both air-saturated and degassed solutions. In this case, the solute used was 2,5-diphenyloxazole because of its high solubility at low temperatures. There is a small increase in light output for air-saturated solutions, while for degassed solutions there is a pronounced peak in the curve.

Discussion

One result shown by these measurements is that the quenching by oxygen of the radiation from a liquid scintillator involves both the concentration of solute and the temperature of the solution. There appears to be a competition between the dissolved oxygen and the solute for the available energy in the solution. It has been shown that for both *p*-terphenyl and 2,5-diphenyloxazole in xylene there is a shift toward lower values for the concentration at which maximum light-output occurs upon the removal of dissolved oxygen (*3*). This can be interpreted as an elimination of the competition by oxygen, thereby permitting smaller concentrations of solute to achieve the same effect before self-quenching becomes important. Lowering the temperature of the scintillating solution should decrease the self-quenching and thereby increase the light output. However, this effect tends to be masked in the case of air-saturated solutions due to the increased amount of dissolved oxygen present at the lower temperature. In the degassed solutions the observed light increase is more pronounced and exhibits a further shift toward lower values for the concentration at which maximum light output is obtained.

Present data are not sufficient for a quantitative description of the mechanism of energy transfer. However, a significant increase in the efficiency of liquid scintillators can be obtained by a suitable application of these results.

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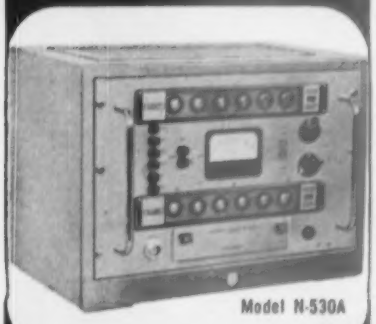

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The recording instrument is shown in Fig. 1. The paper transport mechanism constitutes the major cost of the device. A small amount of machine shop work allows one or more additional speeds to be added. The particular model shown was designed to be used with scalers in this laboratory, which have both external register and timer plugs, so that it may be inserted in a system in a matter of seconds. A scale selector is advantageous for many applications.

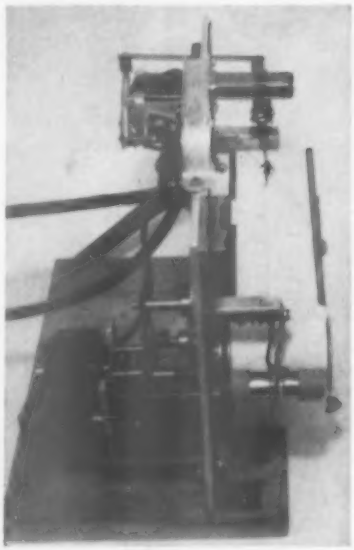

FIG. 1. End view of recorder showing motor and gear train, relay, pen and paper. Subsequent models use insert of ball-point pen instead of glass pen

An example of the data recorded with this instrument is shown in Fig. 2.

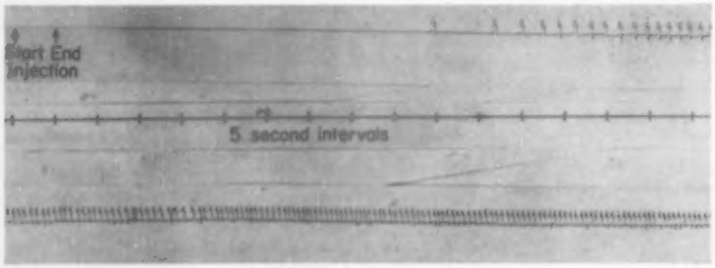

FIG. 2. Tape recording of blood circulation of polycythemic patient treated with P^{32}; P^{32} was injected in one arm and the other arm monitored. Tape was started at time of injection. From superimposed time scale, P^{32} reached monitored arm in 50 sec with activity increasing rapidly. Second line shows slight increase in counting rate some minutes later. To facilitate measurements, plastic rule graduated in time intervals is sometimes used

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Determination of Radio-Cesium in Fission-Product Mixtures

By RICHARD B. HAHN and ROY O. BACKER*
Chemistry Department
Wayne University
Detroit, Michigan

Methods commonly used for determining radioactive cesium in fission products are the precipitation of cesium bismuth iodide (*1*), and the precipita-

* Present Address: Westinghouse Electric Corp., Pittsburgh, Pa.

TABLE 1—Determination of Radioactive Cesium with Dipicrylamine Using Cesium and Potassium as Carrier

Carrier taken (gm)	*Carrier recovered (gm)*	*Gravimetric yield (%)*	*Count corrected for background (cpm)*	*Count corrected to 100% yield (cpm)*	*Counts taken (cpm)*
Cesium carrier					
0.0029	0.0027	93.1	1,045	1,122	1,070
0.0029	0.0025	66.2	976	1,132	1,070
0.0049	0.0045	91.8	977	1,064	1,070
0.0049	0.0042	85.7	921	1,075	1,070
0.0049	0.0043	87.8	768	875	842
0.0049	0.0044	89.8	796	886	842
0.0098	0.0089	90.8	784	863	842
0.0098	0.0087	88.8	756	851	842
Potassium carrier					
0.0029	0.0019	66.0	590	894	890
0.0029	0.0021	72.0	710	985	890
0.0029	0.0018	82.0	614	990	890
0.0049	0.0040	81.5	700	860	890
0.0049	0.0041	83.5	720	860	890
0.0049	0.0036	73.5	700	862	890

TABLE 2—Separation Studies*

	Carrier added (gm)	*Carrier recovered (gm)*	*Gravimetric yield (%)*	*Count corrected for background (cpm)*	*Count corrected to 100% yield (cpm)*	*Counts taken (cpm)*
One scavenging step	0.0049 cesium	0.0043	89.0	800	870	
	0.0098 cesium	0.0090	92.0	1,080	1,170	
	0.0049 potassium	0.0036	73.5	420	570	
	0.0098 potassium	0.0080	82.0	2,400	2,900	
Two scavenging steps	0.0049 cesium	0.0038	77.5	600	775	
	0.0049 cesium	0.0039	79.5	660	830	
	0.0049 potassium	0.0037	75.5	350	464	
	0.0049 potassium	0.0038	77.5	422	544	
Three scavenging steps	0.0049 cesium	0.0036	73.5	28	38	
	0.0049 cesium	0.0035	71.5	29	40	
	0.0049 potassium	0.0039	79.5	19	24	
	0.0049 potassium	0.0038	77.5	23	30	
	0.0049 cesium†	0.0038	77.5	747	957	925
	0.0049 cesium†	0.0037	75.5	736	975	925
	0.0049 potassium†	0.0037	75.5	736	975	925
	0.0049 potassium†	0.0036	73.5	666	907	925

* The following activities were added to all samples: 1.7×10^4-cpm Ce^{144}-Pr^{144}, 1.2×10^5-cpm Sr^{90}-Y^{90}, 1.2×10^4-cpm Ru^{106}-Rh^{106}, 2.8×10^6-cpm Zr^{95}-Nb^{95}.
† 925 cpm Cs^{134} added in addition to the above activities.

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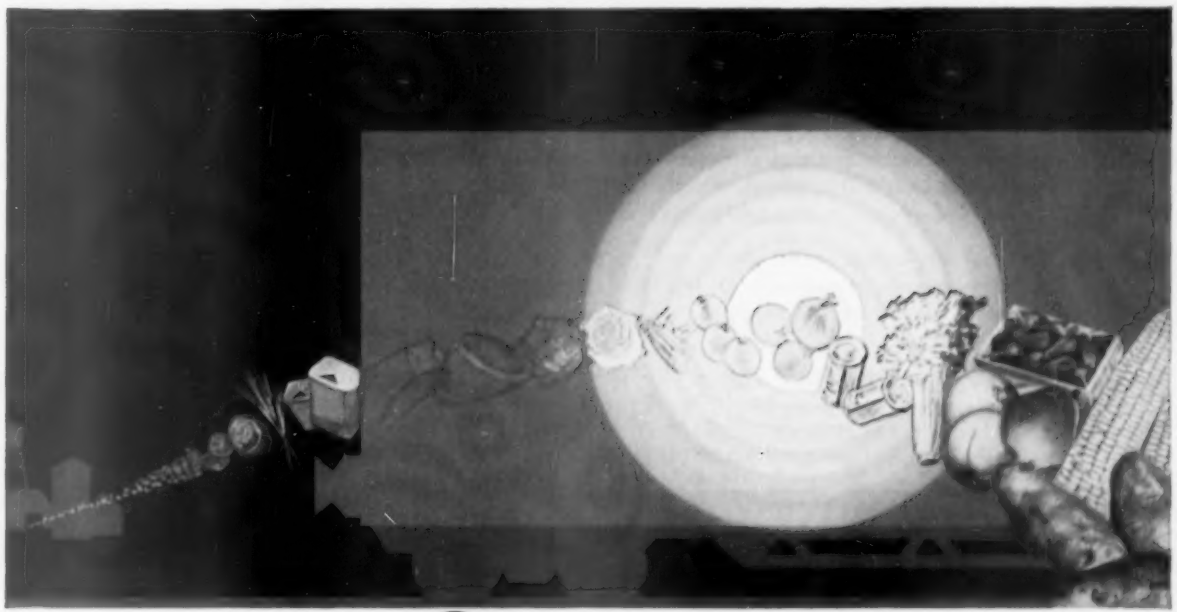

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tion of cesium perchlorate (*2*). However, these methods are not entirely satisfactory.

The cesium bismuth iodide method requires a double precipitation followed by a final precipitation as cesium chloroplatinate. This procedure is complicated and requires the use of costly chloroplatinic acid. The perchlorate method requires working under anhydrous conditions and involves the use of perchloric acid. Because of these difficulties, the study discussed here was made in which other reagents were investigated.

The problem of finding a reagent that will separate cesium from other alkali metals is not encountered in the analysis of fission-product mixtures since rubidium, potassium, and the other alkali metals are not present to any appreciable extent (*3*). Therefore, any method used for the gravimetric determination of potassium probably could be applied to cesium. Among these methods are: precipitation as chloroplatinates (*4*), perchlorates (*4*), picrates (*5*), chlorostannates (*6*), fluosilicates (*7*), dipicrylaminates (*8*), and periodates (*9*).

Dipicrylamine was considered the most promising, hence it was investigated as a reagent for determining radioactive cesium in fission products.

Dipicrylamine (2, 2′, 4, 4′, 6, 6′-hexanitrodiphenylamine) was first used by Poluektov (*10*) for detecting potassium. Sheintsis (*11*) later showed that it could be used for the gravimetric determination of potassium, rubidium, and cesium. These elements form difficultly soluble, crystalline salts with the reagent. The magnesium salt of dipicrylamine is used as the precipitant in these determinations. Quantitative precipitation is achieved by adding an excess of the reagent to cold, slightly acid, aqueous solutions containing potassium, cesium, or rubidium ions.

Experimental

The procedure for determining radioactive cesium was adopted from the procedure given by Welcher (*8*). Two series were run—one in which cesium chloride was used as carrier, another in which potassium chloride was used. The procedure was as follows:

1. Add a known amount of standard carrier solution of cesium chloride or potassium chloride (2–10 mg of Cs or K) to a 40-ml centrifuge tube, then a known amount of radioactive cesium tracer.

2. Add a drop of thymol blue indica-

Reagents

Potassium chloride. 19.0665 gm of C.P. potassium chloride dissolved in distilled water to make one liter of solution. Standardize by precipitating potassium perchlorate (*2*). Solution contained 9.90 mg of K^+ per ml.

Cesium Chloride. 12.6680 gm of C.P. cesium chloride (Foote Mineral Co.) dissolved in distilled water to make one liter of solution. Standardized by precipitating perchlorate (*2*). Solution contained 9.80 mg of Cs^+ per ml.

Dipicrylamine (2, 2′, 4, 4′, 6, 6′-hexanitrodiphenylamine, Eastman Kodak Co.). A 3% solution of magnesium salt prepared by dissolving 12 gm of dipicrylamine in 500 ml of water then adding 5 gm of magnesium oxide. Stirred for an hour, allowed to stand for 24 hr, then filtered.

Cesium-134 (2.3-yr half-life, beta and gamma emitter). Obtained from Isotopes Division, Oak Ridge National Laboratory. Samples in counting range prepared by dilution with 1*M* hydrochloric acid. Standards prepared by evaporating known amounts of diluted solution on 1-in. watch glasses then counting beta particles using mica-window G-M tube (Tracerlab TGC-1) and scaler (Nuclear Instrument and Chemical Corp., Model 162).

tor, then neutralize using sodium hydroxide or hydrochloric acid.

3. Add 5 ml of 3% magnesium dipicrylaminate reagent for each 5 mg of carrier.

4. Stir thoroughly, then cool the mixture in an ice bath. Let stand for one hour with occasional stirring.

5. Filter, using a 1.5-cm filter paper disk in a Hirsch funnel. Wash with 5 ml of ice water, then with 10 ml of diethyl ether.

6. Dry for one hour at 80°–90° C, then weigh and count the precipitate.

7. Correct for gravimetric yield. The factors used are Cs/Cs(D.P.A.) = 0.2327 and K/K(D.P.A.) = 0.08191.

This procedure was followed using varying amounts of cesium chloride as carrier, then repeated using varying amounts of potassium chloride as car-

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rier. The results are given in Table 1.

These data show the radioactive cesium is carried quantitatively on both the cesium and potassium dipicrylamine precipitates. The precision and accuracy is somewhat greater using cesium as carrier. Blanks were run using potassium carrier without added radioactive cesium to determine if the natural radioactivity due to the presence of K^{40} would cause errors. No increase over background count was noticeable.

The fact that potassium may be used as carrier in the dipicrylamine method is important. Inexpensive potassium chloride thus may be used in place of costly cesium chloride as carrier. In the perchlorate method this substitution cannot be made since the radioactive cesium is not quantitatively carried by the potassium perchlorate precipitate.

Separation Studies

To study the efficiency of separation of cesium from other activities, the previous procedure was carried out but activities other than cesium were added. A single precipitation with dipicrylamine did not achieve a good separation from the following activities: Zr^{95}-Nb^{95}, Sr^{90}-Y^{90}, Ru^{106}-Rh^{106}, and Ce^{144}-Pr^{144}. The separation from strontium was especially poor.

To improve the separation, scavenging agents and holdback carriers were studied. The following method was devised.

1. Add 1.00 ml of cesium chloride (or potassium chloride) carrier solution (5.0 mg of Cs^+ or K^+) to a 50-ml centrifuge tube.

2. Add a known volume of the solution to be analyzed, then acidify the solution using 6*M* hydrochloric acid. Avoid adding a large excess of acid.

3. Add ½ ml each of ferric chloride and strontium nitrate solutions. (These solutions contain 10 mg of Fe^{+++} and 10 mg of Sr^{++} per ml.)

4. Add 1*M* sodium carbonate solution, drop by drop with stirring until the solution is basic, then add 2 ml in excess.

5. Centrifuge, transfer the supernate to a clean tube, and discard the precipitate of $Fe(OH)_3$ and $SrCO_3$.

6. Add ½ ml each of ferric chloride and strontium nitrate solutions to the supernate from step 5. Centrifuge, transfer the supernate to a clean tube, and discard precipitate.

7. Repeat step 6.

8. Add a drop of thymol blue indi-

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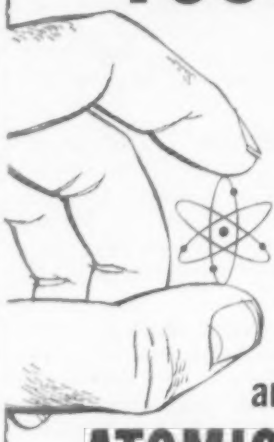

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cator, then neutralize with dilute hydrochloric acid.

9. Add 1 ml of strontium nitrate solution as a holdback carrier.

10. Add 5 ml of 3% magnesium dipicrylaminate reagent.

11. Stir thoroughly then cool in an ice bath. Let stand for one hour in the ice bath then filter. Wash with 5 ml of ice water then with two 5-ml portions of diethyl ether. Dry the precipitate for 1 hr at 80°–90° C, then weigh and count the precipitate.

The efficiency of the procedure was checked by analyzing various mixtures of fission products. Both potassium chloride and cesium chloride were used as carriers. The results are given in Table 2.

These results show that three scavenging steps are required to remove foreign activities. Very little cesium is lost in the scavenging operations. The above method is therefore recommended for determining radioactive cesium in fission products.

Other Methods

Two other methods were studied for determining radioactive cesium.

In the first method cesium was precipitated as slightly soluble cesium aluminum sulfate (*12*) by adding aluminum sulfate solution. In the second method cesium was precipitated as cesium periodate by adding periodic acid (*9*). In both instances low and erratic results were obtained. Hence these reagents are not recommended.

* * *

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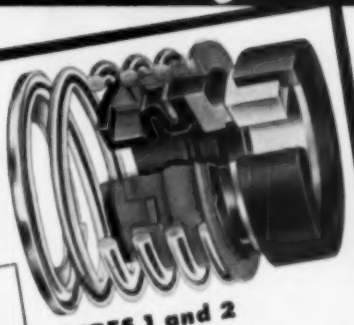

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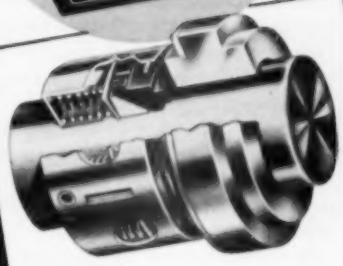

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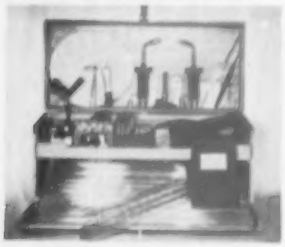

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Alpha-Spectra Ion Chambers

By U. FACCHINI and A. MALVICINI
Laboratori CISE
Milano, Italy

Behaviors of various argon-nitrogen mixtures as filling gases for fast ionization chambers were discussed in a previous paper (*1*). These mixtures are practically insensitive to slight oxygen contamination. We describe here two new types of ionization chambers that provide a very simple and rapid way to detect α-particle spectra.

The first chamber (not shown) is of the gridded type and is filled at atmospheric pressure. The chamber is not pressuretight; during measurement a slow flow of gas (98% A, 2% N_2) is maintained through the chamber.

The thin α-emitting samples are mounted on a metallic disk. The sample change, which is made with the gas flowing, requires only a few seconds.

The chamber design is conventional (*2*). The α-emitting electrode constitutes the base of the chamber and is at zero potential. The base-to-grid distance is 8 cm, and the distance from the grid to collecting electrode is 4 cm. The diameter of the electrodes is 14 cm and that of the sample may be of the order of 6 cm. The total positive voltage applied to the collecting electrode can be 500–3,000 volts or more, without affecting the pulse amplitude. By means of two resistors in the chamber, the voltage is divided between the collecting electrode and the grid; a capacitor between grid and ground avoids a pulse component due to variation of the grid potential.

The collecting electrode is connected to a usual amplification chain and pulse analyzer; the α-particle pulses are formed with an appropriate reflection line. The introduction of a sample in the chamber does not affect the behavior of the chamber, and amplitude and shape of the pulses remain constant when we remove and insert the slide and sample.

The chamber dimensions have been selected to assure that the range of α particles up to 7–8 Mev terminates in the useful volume—i.e., between the emitting electrode and the grid—the gas being at atmospheric pressure. Because of these dimensions the rise time of the pulses is of the order of 6–8 μsec; this value represents the resolving time of the apparatus.

CHAMBER of second type. Sample-change slide and pressure door are shown

The energy resolution of the chamber is about 3% for polonium α particles (5.3 Mev); this resolution and the resolving time indicated are sufficient for most of the routine measurements of α-particle spectra in radiochemical analysis or in studying the alpha radioactivity of air.

The second chamber, shown in the figure, was designed to obtain a better time resolution. The distances between electrodes are 2.2 and 0.7 cm, respectively, and its diameter is less than that of the first chamber. The high voltage for the collecting electrode and the grid is brought into the chamber by means of one Kovar glass seal. The same connection is used also for the output of the α-particle pulses. The filling is made at 3–4 atm so as to exhaust the range of α particles in the convenient region; the resolving time with these conditions becomes around 1 μsec, and the width of the spectral lines of polonium α particles is about 2%.

Samples can be changed in less than a minute by opening the door shown in the figure. After introducing the sample slide into the chamber, the door is closed tightly. After a slow flow of the gas mixture for a few minutes, the chamber is ready for operation.

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A Windowless Flow Counter for Paper Strips

By JOHN M. LOWENSTEIN and PHILIP P. COHEN
Department of Physiological Chemistry
University of Wisconsin
Madison, Wisconsin

A number of paper-strip counters have been described that employ thin-window G-M tubes as radiation counters (*1–6*). However, their low sensitivity is a disadvantage in counting weak radiation from dilute samples. As a more sensitive arrangement for counting paper strips, we constructed a windowless flow counter, having in mind the following aims: low gas consumption, low background, high resolution, and capability of quantitatively reproducible results.*

Properties of Flow Counter

Minimum gas flow rate	15 ml/min
Gas flow rate used routinely	20–30 ml/min
Threshold voltage	1,050 volts
Plateau	1,075–1,700 volts
Slope	Rising from about 1% near threshold to about 3% near continuous discharge
Background	About 10 cpm

Construction

The apparatus consists essentially of a paper-feeding mechanism and a gas flow tube that is mounted over a paper-guide channel (Fig. 1). The gas flow tube is connected to a ratemeter, the output of which is connected to a pen recorder. The drive of the latter is connected to the mechanism that feeds the paper through the counter.

The guide channel for the paper is 1.25 in. wide and 0.013 in. high. Radiation from the paper strip passes through a 0.25-in.-wide slot in the guide channel to the counting tube. The edges of the slot facing the counting tube are bevelled at a 20-deg angle to improve counting geometry. Counting gas enters the top of the counting tube and leaves along both ends of the guide channel, which ensures that the paper is pre-gassed adequately. Two rubber rollers pull the paper strip through the counter—a driver that is linked to the pen-recorder motor by a drive shaft and an idler, which presses the paper firmly against the driver. The driver rubber is harder than that used for the idler, which assures that the diameter of the driver, and hence the rate of pulling the paper through the apparatus, does

* A device of different design, which also uses a windowless counting arrangement, has been described recently. In this model, the radiation counter, paper strip, and paper-strip feeding mechanism are placed inside a tube that is evacuated and then filled with counting gas (*7*).

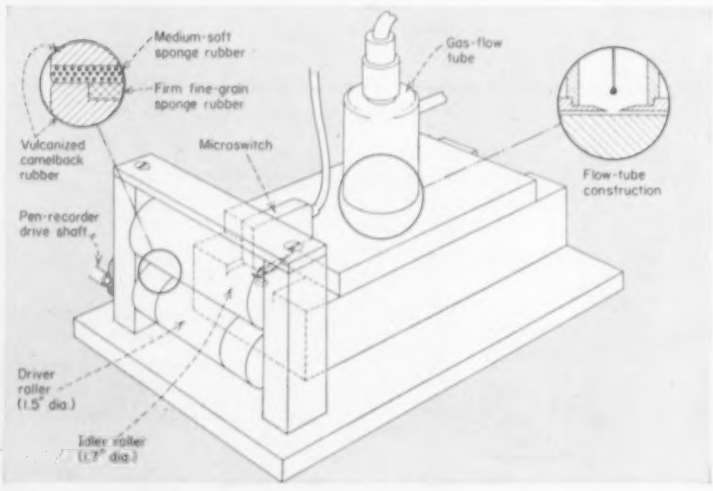

FIG. 1. Windowless flow counter for paper strips

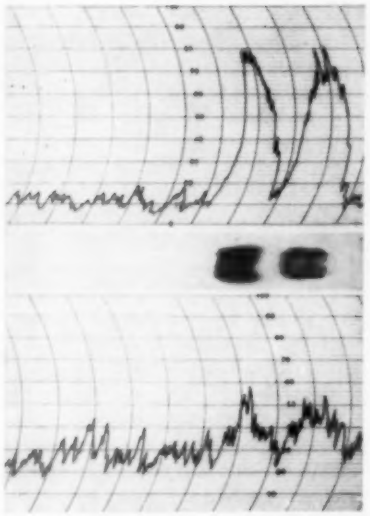

FIG. 2. Chromatogram (center) of radioactive aspartic (at left) and glutamic acids. Top record was made with gas-flow counter (full-scale deflection—100 cpm, chart speed—6 in./hr, flow rate—20 ml/min, ratemeter time constant—45 sec) and bottom record with end-window tube. 0.75 μmole aspartic acid and 1.50 μmoles glutamic acid were spotted on Whatman No. 1 paper; solvent was buffered aqueous phenol (8); developer after counting was ninhydrin. Identical amounts of the acids registered 890 and 840 cpm, respectively, when counted in gas-flow counter at infinite thinness

not vary because of deformations of the driver. The paper-strip feeder and the pen-recorder chart feeder are usually geared to run at the same speeds, but they may be geared to run at different speeds. Paper strips may be any width narrower than 1.25 in.

Operation

To use the apparatus, the paper strip is fed through the guide channel, under the micro switch (which switches on), and through the rollers. The paper slides through smoothly, but there is some risk that it may curl up into the counting tube rather than slide through the length of the guide channel. This risk is overcome by attaching the paper strip to a short strip of very stiff paper (e.g., index-card strips) with cellophane tape. Different strips may be taped together with cellophane tape, and there is no limit to the length of the strip that can be fed through the counter. The ratemeter is switched on, and the gas flow is started (both helium saturated with anhydrous ethanol at 0° C, and 99.05% helium-0.95% isobutane are suitable). The gas flow rate is meas-

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ured by a flow gage. About 15 min are required before the instrument is equilibrated adequately. The flow rate does not have to be readjusted to suit any particular width of the paper strip, and the apparatus records a background rate that is the same whether or not a paper strip is inserted. The full-scale deflection of the ratemeter is adjusted to the desired ratio, the pen-recorder motor is switched on, and the starting points on the paper strip and on the recorder are marked.

At the conclusion of a run the end of the paper strip passes the micro switch (Fig. 1), and the apparatus is switched off automatically. The switch-off position serves as a further reference point on the chart record. (An electromagnetic valve to switch off the flow of gas can also be linked to the microswitch.)

By measuring the distances between the start and finish positions and between reference spots on both the paper strip and on the corresponding chart record, the two types of record were found to compare very accurately. However, to be sure of accurate correspondence in the case of very long strips (e.g., lengths of 20 ft), radioactive reference spots on paper may be inserted with cellophane tape.

Representative results obtained with the counter are shown in Fig. 2. By running several strips through the counter repeatedly, it has been demonstrated that reproducibility is limited only by the statistical considerations of radioassays. A comparison of the performance of the gas flow with that of an end-window arrangement is also shown in Fig. 2—obtained by replacing the gas flow tube with an end-window tube of the same diameter.

Contamination of the counter has been negligible, even after the repeated counting of amino acid spots registering 25,000 cpm.

* * *

This study was supported in part by funds from the National Institutes of Health, National Science Foundation, and the Wisconsin Alumni Foundation.

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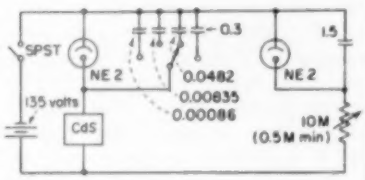
Improved Fallout Meter Using CdS

By LAWRENCE RUBY
University of California
Radiation Laboratory
Berkeley, California



IMPROVED meter circuit

The CdS dose-rate meter described recently* offers the possibility of a simple and inexpensive dosimeter that covers the ranges of interest in fallout measurement. However, in the form of instrument shown, several disadvantages are apparent:

1. The calibration depends on the magnitude of the battery voltage.
2. The device is not self-sufficient in that a separate means of measuring a time interval is necessary.
3. The device is not direct reading in that the counting rate must be calculated to determine the dose rate.

The magnitude of these quantities is arranged to have a one-to-one correspondence on the lowest scale.

The modification shown in the diagram eliminates all these disadvantages by using a null method in which counting rates in two circuits are balanced. The dose rate is then read off the potentiometer dial, which has a nonlinear calibration in terms of radiation intensity. Selection of switch position determines the dose-rate multiplier, which increases by factors of ten. It is, of course, necessary to select neon tubes with the same firing voltage.

* C. C. Klick *et al.*, NUCLEONICS **13**, No. 12, 48 (1955).

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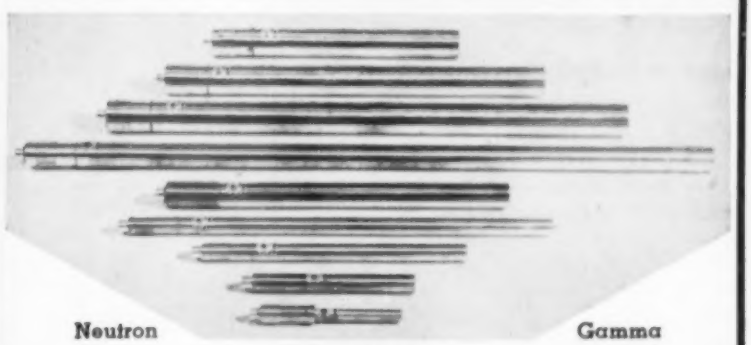

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Counting Efficiency for Np^{239} Beta Rays

By LEON WISH
U. S. Naval Radiological Defense Laboratory
San Francisco, California

The Np^{239} found in neutron-irradiated samples of U^{238} is a measure of the capture of neutrons by U^{238}, the former being the daughter of the 23.5-min U^{239}.

Since it is essential to know the absolute activity or number of atoms of the neptunium, it is necessary to convert the measured counting rate to the absolute activity by determining the counting efficiency. This is simply the ratio of observed counting rate to the actual activity. Thus the problem is to obtain a pure Np^{239} sample with known disintegration rate. This problem can be solved indirectly by counting the alpha rays from the Pu^{239} daughter after the 2.3-day parent has decayed. From the absolute activity of the Pu^{239}, the Np^{239} present at any time during its decay can be calculated since the number of atoms of the daughter originated from an equal number of parent atoms. However, since the Pu^{239} has a half-life of 24,400 yr, there will be very little alpha activity unless sufficient Np is present initially.

Separation of NP^{239}

One hundred twenty milligrams of U^{238} as U_3O_8 were bombarded with neutrons in the Arco Materials Testing Reactor for 2 hr. The oxide was dissolved in HNO_3, 10 mg La^{+++} carrier were added, and $La(OH)_3$ was precipitated with NH_4OH.

After washing, the hydroxide was dissolved in HNO_3, Ag^+ and $S_2O_8^=$ were added, and the La was precipitated as the fluoride with HF. The supernatant from the oxidized fluoride was evaporated to dryness and 10 mg La^{+++} carrier was added plus Zr(IV) holdback. The Np was reduced with NH_2OH·HCl and LaF_3 precipitated again and dissolved in H_3BO_3 and HNO_3. This oxidized-reduced fluoride cycle was repeated twice and finally the LaF_3 was dissolved as above and $La(OH)_3$ precipitated with NH_4OH. This was dissolved in HCl and adjusted to pH = 1.

The HCl solution was added to a Dowex-50 cation column at 87 °C and the Np activity eluted with 0.7*M* ammonium lactate solution at pH = 3. Activity peaks were eluted on both sides of the Np and only the center cuts of the desired isotope were used to reduce contamination. The lactate solution was evaporated with fuming HNO_3 to destroy the lactic acid, the residue was taken up in HCl, and 10 mg La carrier was added. The hydroxide was precipitated with NaOH, thoroughly washed, and dissolved in HCl plus 1 drop of concentrated HNO_3. The solution was saturated with HCl gas and added to a Dowex-2, X8, 200–400-mesh anion resin column, 2 mm by

TABLE 1—Simultaneous Electrodeposition of Pu and Np

Np added (cpm)	*Pu added (cpm)*	*Np electrodeposited (%)*	*Pu electrodeposited (%)*	*Difference (%)*
90,655	8,305	98.1	98.7	−0.6
90,655	8,305	92.0	97.6	−5.6
105,980	8,305	96.9	95.8	+1.1
29,544	8,305	80.0	79.8	+0.2
29,544	8,305	73.2	73.1	+0.1

TABLE 2—Pu^{239} Growth from Np^{239}

Np-1				*Np-2*				*Np-3*				*Np-4*			
Time after t_0 (hr)	*Theor. growth (%)*	*Exptl. growth (%)*	*Diff. (%)*	*Time after t_0 (hr)*	*Theor. growth (%)*	*Exptl. growth (%)*	*Diff. (%)*	*Time after t_0 (hr)*	*Theor. growth (%)*	*Exptl. growth (%)*	*Diff. (%)*	*Time after t_0 (hr)*	*Theor. growth (%)*	*Exptl. growth (%)*	*Diff. (%)*
24.2	21.3	56.6	+35.3	25.3	22.0	54.0	+32.0	26.7	23.0	46.3	+23.3	27.2	23.2	50.8	+27.6
43.9	39.0	63.2	+24.2	44.6	39.2	58.7	+19.5	46.0	41.0	52.2	+11.2	46.3	41.1	50.7	+19.6
68.0	57.8	57.3	− 0.5	69.0	58.0	57.1	− 0.9	70.0	59.0	58.8	− 0.2	71.0	59.5	57.2	− 2.3
92.0	68.1	67.8	− 0.3	93.0	68.5	69.2	+ 0.7	94.0	69.0	69.7	+ 0.7	95.0	69.5	69.8	+ 0.3
116	75.8	75.8		117	75.8	75.6	− 0.2	119	77.0	76.5	− 0.5	121	77.0	76.7	− 0.3
145	82.9	82.1	− 0.8	142	82.5	81.1	− 1.4	144	82.7	84.0	+ 1.3	142	82.5	83.6	+ 1.1
167	87.1	88.4	+ 1.3	168	87.3	87.2	− 0.1	189	90.0	89.5	− 0.5	192	90.5	90.3	− 0.2
213	92.7	92.8	+ 0.1	215	93.6	92.4	− 1.2	217	93.1	91.5	− 1.6	219	93.2	92.1	− 1.1
267	95.8	95.3	− 0.5	263	95.9	94.8	− 1.1	265	96.0	95.3	− 0.7	285	96.9	97.4	+ 0.5
307	97.6	96.2	− 1.4	287	96.9	97.7	+ 0.8	313	97.7	97.7		333	98.1	99.2	+ 1.1
357	98.8	99.0	+ 0.2					361	98.8	98.7	− 0.1	432	99.6	102.0	+ 2.4
456	99.7	100.7	+ 1.0	430	99.5	101.7	+ 2.2	456	99.7	101.0	+ 1.3				

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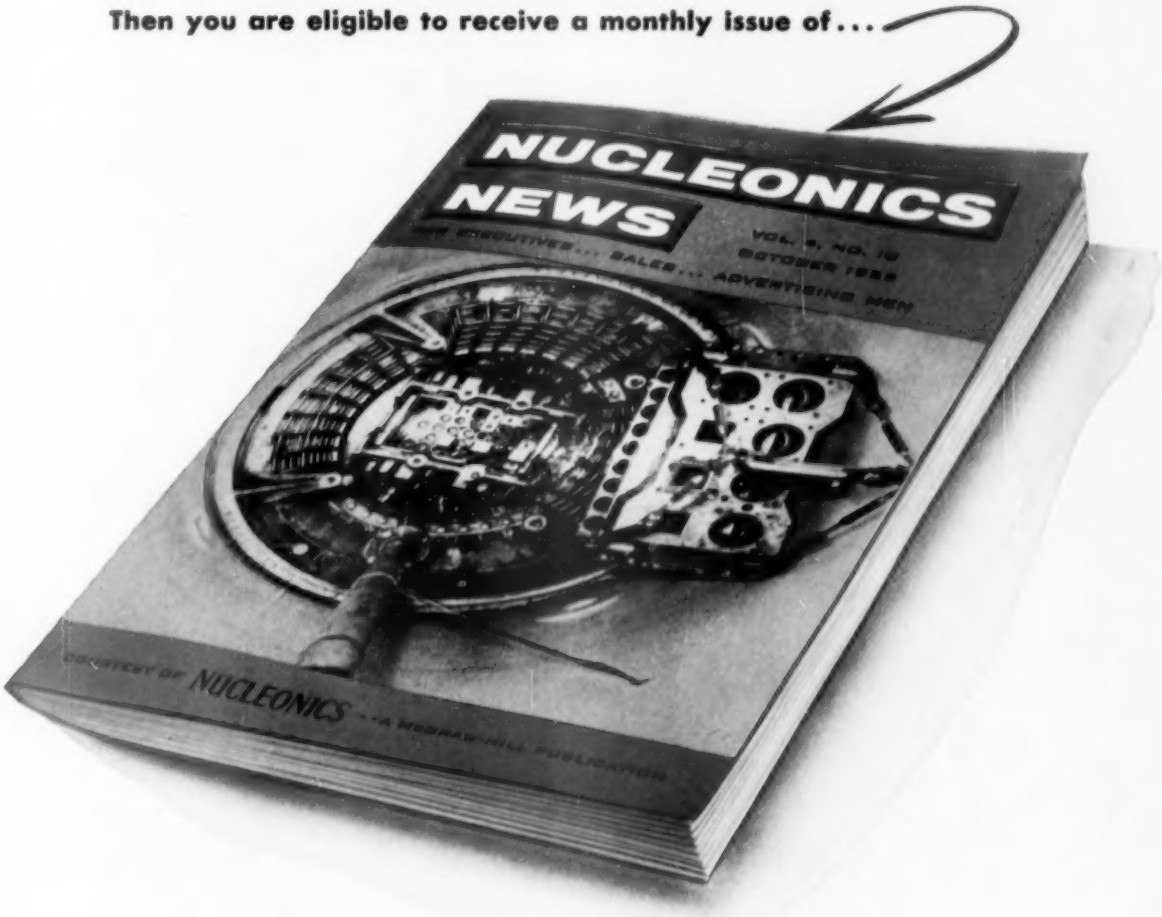

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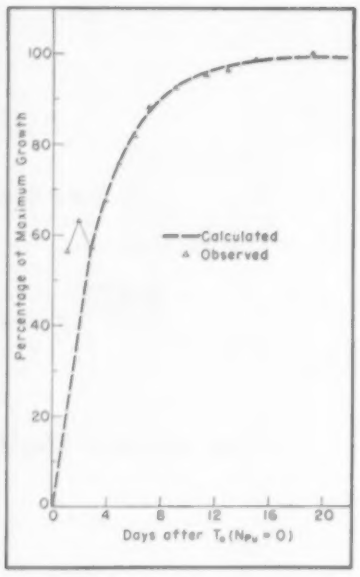

COMPARISON of observed and calculated growth of Np^{239}

10 cm. The La and any rare earth activities were washed out with concentrated HCl; the Pu activity was eluted with concentrated HCl saturated with $NH_2OH \cdot HCl$ and NH_4I, the time of this separation being considered as the zero time of growth for the Pu^{239} daughter activity.

Concentrated HCl containing 10% of concentrated HNO_3 was passed through the column to oxidize any U that might have been reduced by the preceding elution, and finally the Np was removed with 6*N* HCl.*

Electrodeposition of Np

The 6*N* HCl solution was evaporated with HNO_3 to remove the HCl, and the residue taken up in 50% saturated ammonium oxalate solution to 10 ml in an electrolysis cell. The Np was deposited on platinum from an ammonium oxalate solution at a potential of 8–9 volts and current of 1–2 amperes

*L. Wish and M. Rowell, "Sequentia Actinide Analysis" (to be published).

TABLE 3—Half-life of Np^{239}

Decay (days)	*Number of points*	*Half-life (days)*	*Standard deviation (days)*
23	46	2.343	0.002
20	35	2.347	0.008
28	35	2.348	0.002

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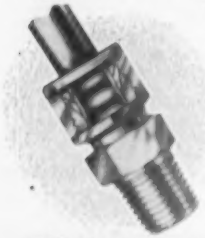

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TABLE 4—Counting Efficiency of Np^{239} Electrodeposited on 4-mil Platinum

Al absorber added						
0 (mg/cm²)		*50.3 (mg/cm²)*		*268 (mg/cm²)*		
Counter		*Counter*		*Counter*		
No. 1	*No. 2*	*No. 1*	*No. 2*	*No. 1*	*No. 2*	*Shelf*
62.4 ± 1.0	63.0 ± 1.0	2.75 ± 0.04	2.72 ± .03	0.197 ± 0.03	0.196 ± .002	1
39.9 ± 0.6	40.4 ± 0.4	1.74 ± 0.03	1.72 ± .03	0.126 ± .001	0.126 ± .001	2
24.8 ± 0.4	25.5 ± 0.5	1.09 ± 0.02	1.09 ± .02	0.0817 ± .0008	0.0825 ± .0014	3
9.03 ± 0.15	9.27 ± 0.02	0.412 ± 0.005	0.416 ± .006	0.0343 ± .0008	0.0353 ± .0008	4
4.09 ± 0.07	4.13 ± 0.07	0.200 ± .004	0.201 ± .005	0.0184 ± .0006	0.0189 ± .0003	5

first for 45 min in acid and secondly for 60 min in basic medium.

Since some Pu^{239} had grown between the zero time of separation and the electrodeposition, and if this zero time is valid, it is essential not only to plate it out together with the Np but also to the same extent. Thus, known amounts of Pu^{239} and Np^{239} tracers were mixed and electrodeposited simultaneously. The results are shown in Table 1. In all cases except one the percentage of each isotope deposited was within 1% (well within the experimental error) and the zero time of separation was not affected.

The growth of the Pu^{239} daughter was followed until the alpha activity was constant. Table 2 gives a comparison of the experimental versus the theoretical alpha growth for four aliquots of the first Np solution. In all cases after 48 hr, the observed activity agreed with the calculated activity. Since the ZnS screen of the scintillation counter has a definite threshold for counting beta-ionization pulses, the results of the first 2 days were high. This threshold was exceeded with the initial high Np^{239} activity; thus high counting rates resulted. However, when the Np had decayed sufficiently there was no interference. The illustration compares the observed growth with the growth curve calculated on the basis of a 2.34-day Np^{239} half-life.

The decay of Np^{239} was followed in a gamma-ray high-pressure ionization chamber to check the separation and purification and at the same time obtain an accurate half-life of the nuclide. Table 3 gives the results from three different bombardments. The values and deviations were calculated by the method of least squares. The deviation of the second sample is larger than the other two and is probably the result of a lower activity, which necessitated measurements in the low range limit of the ionization chamber. Average of the three determinations is 2.346 days with a deviation of 0.004 days.

Counting Efficiencies

Alpha-ray growth and subsequent efficiency determinations were carried out with Np on four aliquots from each of two samples. Table 4 gives these results for two proportional side-window counters. Each electroplated sample on Pt was mounted on a brass disk and covered with pliofilm of ~1 mg/cm² thickness. The over-all averages show a deviation from the mean of slightly less than 2%.

With this counting efficiency it became possible to determine the absolute disintegration rate or the number of atoms of any unknown sample of Np^{239} by measuring its counting rate under the specified conditions. The number of atoms is obtained from the equation, $N = I/\lambda$, where λ is the disintegration constant and I the absolute activity. It also became possible to calibrate other counting apparatus by means of a sample of Np^{239} of known activity.

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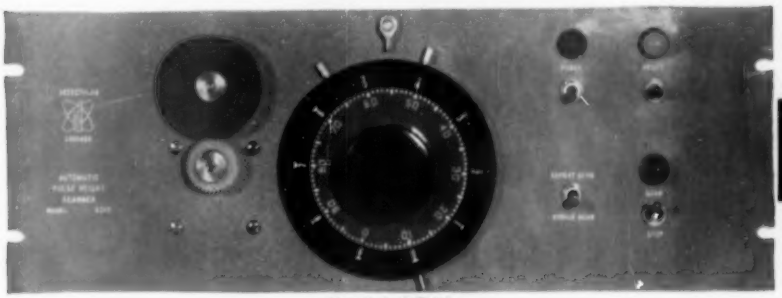

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Thermal-Neutron Diffusion Lengths for Water, Lucite, Furfural, and an Expanded Plastic

By L. R. HEINTZÉ*
Brookhaven National Laboratory
Upton, New York

Investigations of the thermal-neutron diffusion length in various substances have been fairly numerous, but the results are often in somewhat poor agreement. This paper presents our measurements of the diffusion lengths, L, in several substances.

Experimentally determined values of L can be of use in investigating the effect of binding on cross section. The free-hydrogen total cross section is about 20 barns, and binding increases this value to a theoretical maximum of about 80 barns. However, the binding has another effect: it tends to modify the strongly forward angular distribution of scattered neutrons. Neither of these effects of binding can be calculated readily, and so there is interest in comparing diffusion lengths (and hence transport mean-free-paths) in several substances. In this way one can determine how the effect of binding is different for different hydrogenous media and with this information seek a way to predict diffusion lengths without the need for measurements.

A later paper will present a comparison of more than a dozen values of L_{H_2O}, the methods used to find them, and a conclusion that can be drawn from the comparison (*1*).

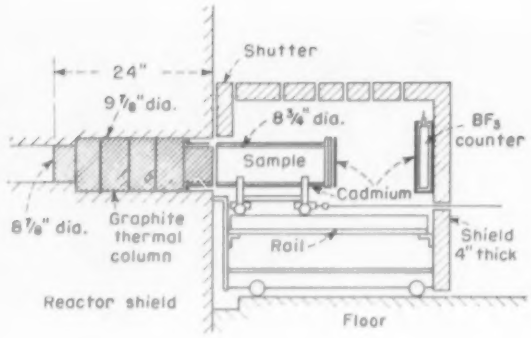


FIG. 1. Cross section of experimental arrangement used to measure diffusion lengths for thermal neutrons. Thermal column consists of 6 disks, each 4 in. thick

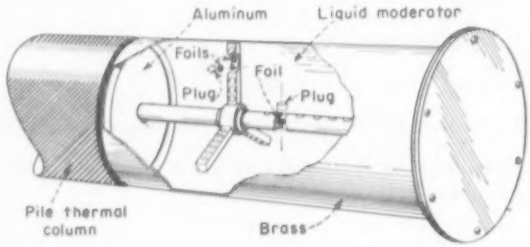


FIG. 2. Cutaway view to indicate method used to position foils for measurements with water

Theoretical Background

Thermal-neutron diffusion length can be defined in terms of an infinite plane thermal-neutron source and an infinite medium by stating the variation in flux with distance from the source. The value of the flux ϕ at any distance from the source x would be given by $\phi = \phi_0 e^{-x/L}$. Since neutron sources and absorbers are finite, however, there exists neutron leakage from the absorber that must be taken into account. Thus, it is necessary to measure both the flux variation with the perpendicular distance from the source plane and the flux variation with distance parallel with the plane. To simplify the geometrical considerations a circular source plane and right cylindrical absorber of equal diameters were used, and the fluxes were measured along the absorber's axes and radii. The axial measurement gave the relaxation length, λ, and the radial measurement the extrapolated radius, R. Then, if there are no harmonics but the first present and the flux distribution is symmetrical about the axis,

$$\frac{1}{L^2} = \frac{1}{\lambda^2} - \left(\frac{2.4048}{R}\right)^2.$$

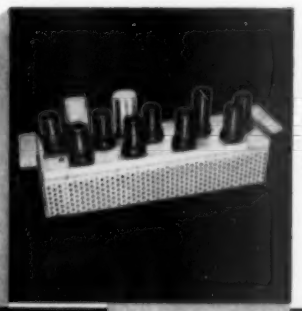
Experimental Procedure

A thermal column of the BNL reactor consisting of a graphite cylinder 9⅞ in. in diameter and 20 in. long was used as a thermal-neutron source. To this was added a cylindrical graphite pedestal 4 in. long and 8¾ in. in diameter, which matched the diameter of the moderators that were measured (Fig. 1). The pedestal's curved side was covered with 0.030-in.-thick cadmium, as was the annular section exposed by the 9⅞-in.-dia thermal column. This was done to prevent thermal neutrons from reaching the sample except those that passed through the plane face of the pedestal.

The liquid moderators (water and furfural) were contained in a brass tank (Fig. 2); the tank end in contact with the thermal column was ⅜ in. 2S aluminum. The side and back of the tank were cadmium covered to prevent thermal neutrons from being reflected back into the tank from the neutron-gamma shield in which the tank was placed.

Lucite foil holders were used in the

* PRESENT ADDRESS: Atomic Power Equipment Dept., General Electric Co., Schenectady, N. Y.



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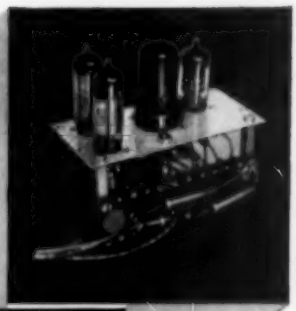

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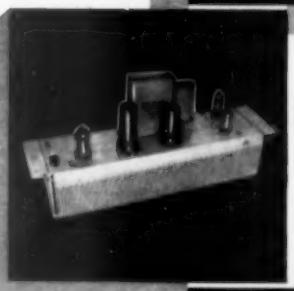

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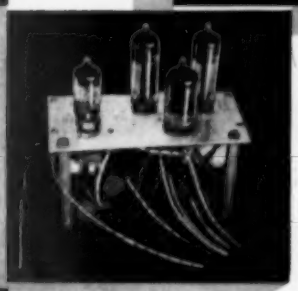

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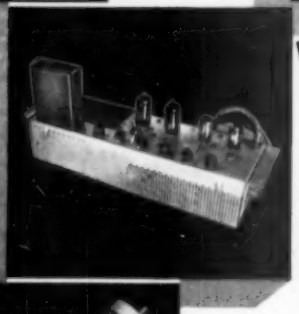

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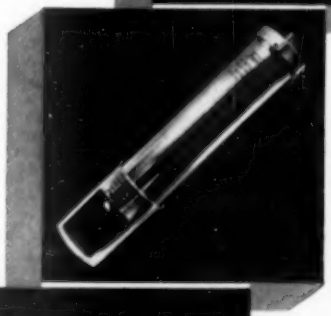

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water; the axial measurements were made using a 0.475-in.-dia Lucite rod with the foil holes spaced 0.500 in. apart. The foils in all cases were indium, 0.220 in. in diameter, 0.010 in. thick, and were positioned so that their axes were perpendicular to the axis of the thermal column. This was done to minimize shadowing, and to assure that their sides would be equally radioactive.* The radial measurements were performed by positioning the foils in a Lucite spider having three co-planar radial legs 120 deg apart. Again, 0.500-in. foil spacing was used, and the activities of the foils equidistant from the axis were averaged.

The furfural measurements were made in essentially the same way as the water ones, except that $\frac{1}{32}$-in.-thick 28-aluminum foil holders were used, and the foil spacings were 1.000 in. on the axis.

For the Lucite and special plastic measurements a cylinder of each was constructed by using a stack of discs $8\frac{3}{4}$ in. in diameter and about 1 in. thick. A central rod through the stack was the axial foil holder. Radial measurements were done using a diametrical slot milled in a disk, with a foil-holding slide in it. The axial rods and the radial slides were made of the same materials as the respective moderators. The foil holes were spaced 0.500 in. apart in both axial and radial pieces. As in the case of the liquid moderators the two solid cylinders were covered side and rear with 0.030 in. cadmium sheet. The activities of the radial foils equidistant from the center were averaged as before.

All exposures were made in pairs—one exposure "bare"; i.e., no cadmium between the thermal column and the moderator; and the other with a 0.030-in.-thick cadmium disk between the moderator and thermal column. This was done because there were epithermal neutrons coming out of the thermal column, and it was necessary to isolate the activity caused by thermal neutrons. This method of obtaining the cadmium difference is rather unconventional since the usual procedure is to use bare and cadmium-covered foils. Using bare foils and cadmium over the source is much easier and probably more accurate.† The reason for this is the small overlap between the cadmium resonance and the indium resonance; surrounding an indium foil with cadmium will not only suppress absorption by the 1/v region of the indium cross section below the 1.4-ev resonance but also will eliminate a small section of the resonance capture. This effect has been studied by Kunstadter (*3*); he reports that a correction to the indium activity of about 11% (when 0.030 in. cadmium is used) normally is required. In our present experiments this correction is not necessary because there is an appreciable amount of moderator between the cadmium outside the samples and the indium foils within, and any effect of the overlap of the indium and cadmium resonances is dissipated in the scattering that takes place between the neutrons, entering at the sample

* In addition, the foils were counted on both sides, and the results averaged for each foil. This procedure was followed for all four moderators and for both radials and axials.

† It has recently been found that Allison, et al., also used this method in their measurement of L in water (*2*).

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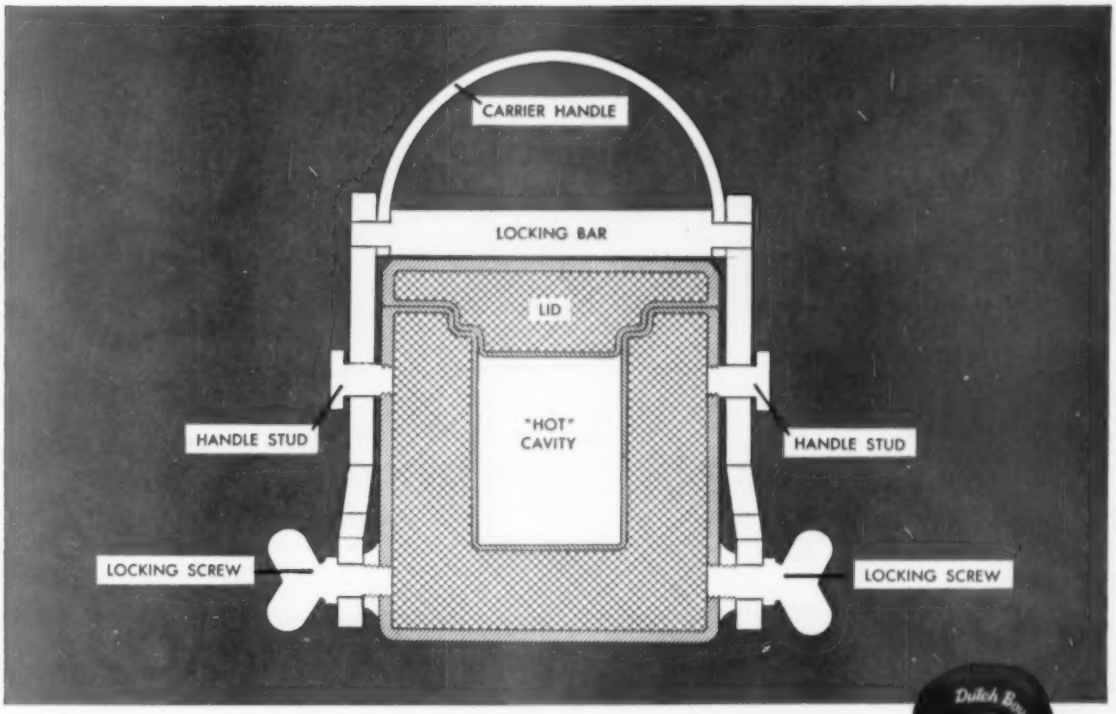

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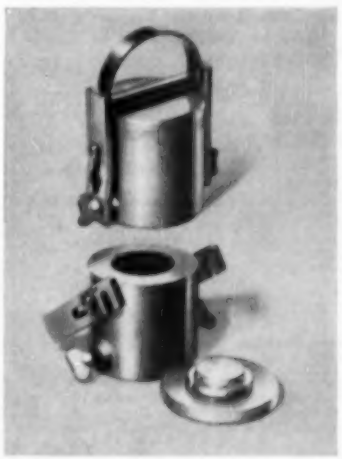

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Measured Diffusion Lengths

Material	*Density* (gm/cm^3)	*Diffusion length, L* (*cm*)	*Implied H transport cross section* (*barns*)
Water, H_2O	1.00	2.86 ± 0.03	31.2 ± 0.6
Lucite, $C_5H_8O_2$	1.18	3.14 ± 0.03	31.9 ± 0.7
Furfural, $C_5H_4O_2$	1.16	5.57 ± 0.14	35.5 ± 1.8
Expanded Plastic,* $C_{7.47}H_{8.20}$	0.504	6.73 ± 0.21	34.6 ± 2.1

* The expanded plastic was 99% by weight a high styrene/butadiene copolymer and 1% dinitroso-pentamethylene-tetramine blowing agent. It was found by chemical analysis to consist of 8.27% hydrogen and 89.68% carbon; the remaining 2.05% was probably metallic impurities, nitrogen, and oxygen.

face and their arrival at the foils.

Each pair of exposures was done as closely together as possible to minimize the possibility of a reactor power-level change. To be certain that each of the two samples received approximately identical exposure a large cadmium covered $B^{10}F_3$ counter was used to monitor the flux. The counter was placed inside the shield that surrounds the sample, and the output was fed into a scaler and a recording counting-rate meter. These instruments recorded the total flux during the exposure and the instantaneous flux variation, respectively. The bare-to-cadmium ratio as computed from the scaler readings would ideally be unity, but a slight source flux variation could not be avoided. The ratio usually differed from unity by 1% or less. The ratio was used as a correction factor as will be explained below. The instantaneous flux record was used to determine whether the flux during exposures was essentially constant.

The special plastic, having an average density of 0.50, was exposed for one hour each time. This exposure was sufficient to produce a satisfactory foil activity since the plastic's relaxation length was fairly great. The water, Lucite, and furfural, having much shorter relaxation lengths (and higher densities), were each exposed 2 hours. The foils farthest from the thermal column were counted first since they had the least activity. Foils were not counted for at least 10 minutes after the end of exposure to allow the short-lived beta activity of the indium to die out. Amperex-120 series beta-gamma G-M tubes mounted in lead pigs having 1½-in.-thick walls were used for the foil counting.

Computation, Correction

Each exposed indium foil and a thallium foil "standard" were counted in at least 6 (usually 12) counters. The thallium foil was used to find an intercalibration factor for each counter.* The raw foil activities were then

* The beta-gamma counters are energy-sensitive to beta particles and a "standard" foil was needed that emitted betas with essentially the same energy as indium. Thallium was chosen for this reason; it is also cheap and has long-lived β activity.

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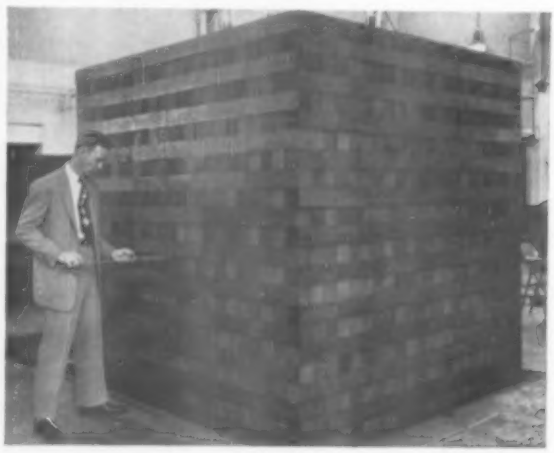

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corrected for counter backgrounds, dead times, count time (5 min in every case), and counter calibration factors. These computations, performed on a Remington Rand electronic computer, were of the form

$$\text{Relative cpm} = \left[\left\{\frac{C}{T} + \left(\frac{C}{T}\right)^2 \tau\right\} - B\right] \frac{e^{\lambda t}}{F}$$

where C = total number of counts, T = count time (5 min), τ = counter deadtime, B = counter background, λ = decay constant (0.012803 min^{-1} for indium), t = time from end of exposure, F = counter calibration factor. No correction for possible foil weight variations was necessary; it had been previously ascertained that the activities of indium foils about 0.010 in. thick were independent of small weight variations (*4*).

As mentioned previously, the bare-to-cadmium monitor ratio was used as a correction factor. It was assumed that a pile power change was the only factor that could have caused a variation in the monitor total counts, so the foil activities were corrected for this power change. Since the monitor readings between a bare and a cadmium exposure usually differed by not more than 1%, it was impossible to ascertain where the change occurred or whether the power was increasing or decreasing slowly throughout the exposure(s). Thus, this correction was not completely accurate. The correction itself consisted of merely multiplying the average activity of each "cadmium covered" foil by the bare-to-cadmium monitor ratio prior to finding the cadmium difference. The cadmium differences then were used to find the relaxation lengths and the extrapolated radii.

For the relaxation lengths: $\lambda = 0.43429\ \Sigma x^2/\Sigma xy$, where x = foil separation (x is measured from the center of the stack so that $\Sigma x = 0$) and y = $\log_{10}$ of the foil activities.

To find the extrapolated radii, R, we fitted the foil-activity curves to Bessel function curves using a least-squares fit method. R is then the point at which the J_0 curve crosses the x-axis. Since the steps are rather involved, they are not included in this paper.

The possible errors listed with the results were found in the usual way; i.e., they were based upon the total number of counts for each foil.

It should be pointed out that Lucite may not have been the best foil-holder material to use in the water measurements due to the fact that the diffusion

lengths of the water and Lucite differ by about 0.3 cm. The temperatures of the media were about 20–22° C.

Results

The table lists the diffusion lengths of the materials measured.

The effect of scattering on cross section and angular distribution is almost the same for all of the measured substances, and for all practical purposes the transport cross section of hydrogen in hydrogenous media can be taken as about 33 barns, which is the average of the above substances.

A Maxwellian average of the hydrogen total cross section from 0.01–0.1 ev, when $kT = 0.025$, gives 34.2 barns. It would appear that in the laboratory system the scattering of neutrons by these molecules is almost symmetrical.

* * *

The author is especially indebted to H. J. Kouts who suggested the method of measurement as well as the theoretical considerations involved in the measurements and computations. Thanks are also due K. W. Downes, G. A. Price, and R. Sher. Much of the foil counting, machining, etc., was done by W. Budd, R. Rice, A. Sabosto, R. Sick, A. Tierney, J. Titmus, and V. Walsh. Most of the calculations were patiently and carefully done by J. Meyer and H. Connell, with an assist from Remington Rand. The major part of this work was supported by the U. S. Air Force through Pratt and Whitney Aircraft, and the remaining portion by the Atomic Energy Commission.

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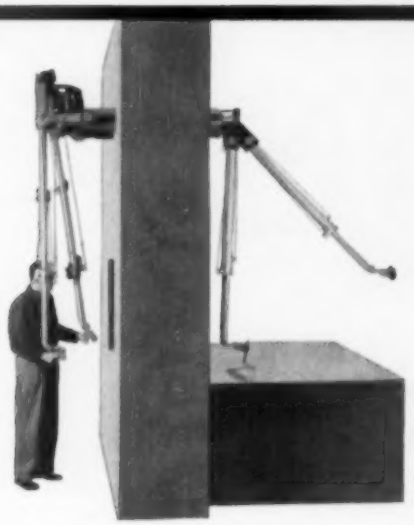

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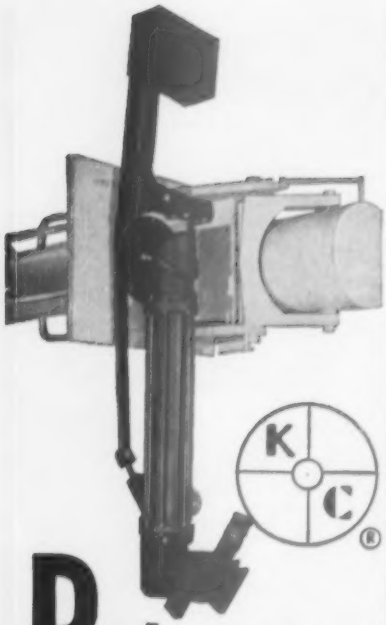

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TECHNICAL ADVANCES

High-Energy Physics— Where Do We Stand? Understanding is growing but mysteries still abound on the frontiers of high-energy physics. All the "heavy" mesons now seem to have the same mass, but it's difficult to understand why they differ in spin and parity. "Strangeness" (NU, May '55, p. 34) has been widely accepted as a new quantum number to explain the production and decay of the many new particles, but no one understands its physical basis. What follows is an account of some of the newer developments at the sixth high-energy conference held at the University of Rochester, April 3–7.

The new particles. The central problem in high-energy physics arises from the recent discoveries of new particles, so many of which are now known that it has become unesthetic, if not entirely absurd, to think of them all as "elementary." Most of them are unstable, decaying rapidly into lighter particles that are often also unstable. There are now more than 25 kinds of particles known, most having been discovered within the last few years. The original announcements referred to them as V particles because of the characteristic appearance of their decay fragments in cloud chambers. Later, when their masses could be estimated, they were classified either as heavy mesons (particles heavier than pi-mesons and lighter than protons) or hyperons (particles heavier than neutrons but not identical with ordinary nuclei).

***K*-mesons.** It is now clear that the heavy mesons, also known as K-mesons, all have the same mass (965.5 electron masses) within uncertainties of the order of 0.1%. What distinguishes a specific "kind" of K-meson from other kinds is simply its mode of decay. Six essentially different decay modes have been identified with certainty, the most frequent mode being a decay into a mu-meson and a neutrino, and the least frequent a decay into one charged and two neutral pi-mesons. The most attractive interpretation of these facts is, of course, that there is only *one* kind of K-meson possessing several modes of decay; such situations are very frequently met in ordinary atomic and nuclear physics. But an obstacle to this hypothesis has been developing, for it appears from some experiments that the K-mesons do not all have the same spin and parity. The interpretation of the K-meson degeneracy is therefore not yet clear.

"Stangeness." Another striking clue to the interpretation of the new particles is the principle of "associated production." It appeared from the early observations that "strange" particles (heavy mesons and hyperons) are never produced singly. So much evidence in support of this has accumulated by now that it has been adopted as a principle, and the consequences that it has helped to develop occupied a large part of the theoretical discussion of this conference. It has been found possible to account for this and other experimental facts by introducing a "strangeness" quantum number, taking on the values -2, -1, 0, and $+1$. The familiar particles (neutron, proton, pi-meson) have strangeness 0, and an assignment can be made to all other particles so that their production and decay properties follow simple selection and conservation rules. Such a scheme is, of course, almost completely *ad hoc*, and the physical content of the idea is not yet understood.

Our present position with regard to the new particles can be summarized by saying that there appears to be very many of them (perhaps even more than have so far been seen), that one outstanding group of them (the K-mesons) seem *almost* to behave like different states of one particle, that they are produced at least two at a time, and that their production and decay can be described as the manifestations of a new and mysterious quantum number, the "strangeness."

Professor Markov of the USSR outlined an alternative description of mesons and hyperons in terms of a sequence of isobaric states of the nucleon which, together with some simple and reasonable rules, can be built into an algebra of the elementary particles whose consequences are very similar to those of the "strangeness" schemes. Time did not permit full discussion of the Russian theory, but it appears to be original and provocative.

The antiproton. Perhaps the most remarkable experimental development of the past year was the discovery of the antiproton at the Bevatron in

Berkeley, together with the measurement of its cross section for interaction with ordinary nuclei. Segrè reported on the Berkeley work, giving as one of the more significant results the observation that the cross sections for antiprotons are consistently twice those for ordinary protons. This fits a prediction that had been made by Teller on the basis of a theory of nuclear forces that was briefly presented at the conference. There is a point of contact between this theory and the one proposed by Markov: in both descriptions, pi-mesons are described as bound states of nucleons and antinucleons.

Field theory. In general quantum field theory, progress was reported in the development of fundamental theorems by analogy with dispersion relations of optics. In this work, the emphasis is on the description of observable initial and final states of interacting systems; conventional field theory tends to emphasize the details of the interaction, which are in principle hidden from us. Unfortunately, discussions at the conference raised doubts about the proposed program.

Russian work. There was considerable interest in the state of Soviet high-energy physics because of the presence of three Russian physicists. Since the recent publication of experimental work from the Moscow 660-Mev synchrocyclotron, which is the largest in the world, it has been clear that the Russians are doing excellent work. We have also learned that the Russians are constructing ultra-high-energy machines, one of which, at 10 Bev, is close to completion. The theoretical discussions of the conference indicated that, although they may not be developing startling and original theories to any great extent, the Russians are well versed in the techniques of modern field theory. Their claim to be counted in the first rank in modern physics seems justified.

The Soviet physicists attending were professors Veksler, Markov, and Silin, all of the Lebedev Institute of Moscow. Each reported on several phases of recent research. The Russians were generous of their time and information outside of formal sessions; Professor Veksler was particularly affable and spoke at length and in detail about the current status of Russian physics.

* * *

We are indebted to Prof. E. M. Hafner of the University of Rochester for this account of developments at the sixth high-energy conference.

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The first volume to appear, vol. 3, "Power Reactors" (NU, Feb. '56, p. 76), and the next six (vols. 2, 4, 7, 14, 15, 16—reviewed below) underline the vast storehouse of knowledge opened at the Geneva Conference.

The remaining volumes of the proceedings of the Geneva Conference on the Peaceful Uses of Atomic Energy were scheduled for publication in April. These are: vol. 1, "The World's Requirements for Energy; The Role of Nuclear Power"; vol. 5, "Physics of Reactor Design"; vol. 6, "Geology of Uranium and Thorium"; vol. 8, "Production Technology of the Materials Used for Nuclear Energy"; vol. 9, "Reactor Technology and Chemical Processing"; vol. 10, "Radioactive Isotopes and Nuclear Radiations in Medicine"; vol. 11, "Biological Effects of Radiation"; vol. 12, "Radioactive Isotopes and Ionizing Radiations in Agriculture"; vol. 13, "Legal, Administrative, Health and Safety Aspects of Large-Scale Use of Nuclear Energy."

These handsomely edited and bound volumes (NU, Oct. '55, p. 90) contain all papers submitted to the conference, including authors' corrections and discussions following each paper presented orally at the conference. Some illustrations are included that were not available for the original individually printed papers.

Prices are: Vols. 1, 2, 10, 11—$8.00; vols. 3, 4, 15—$7.50; vols. 5, 6, 12—$9.00; vols. 7, 8, 9—$10.00; vol 13—$7.00; vol. 14—$6.50; and vol. 16—$5.00.

2—Physics; Research Reactors

Background on basic nuclear physics and descriptions of the construction and operation of research reactors are covered in this volume.

Twenty papers are included on special topics in nuclear physics, 12 papers on fission physics; and 22 papers on research reactors from the standpoints of design, operating experience, type selection, and use in research and testing programs. The discussion periods emphasized the fast-breaking nature of work in this field—latest experimental results were presented as communications were received from the speakers' laboratories. Comparison of techniques and results crystallized concepts and added impetus to further improvements and new data.

Nuclear physics papers cover such subjects as: inelastic neutron scattering (gamma rays from, and angular distribution of), neutron diffraction research, neutron decay, structure of molecules and liquids, and physics research with reactors. Fission physics includes work on: fission and nuclear theory, quantities, times involved, angular correlations, energy loss of fission fragments, photoeffect, and fission near threshold. Reactor papers cover their uses in science and technology, as well as useful information on costs and on selecting a type of reactor for research or testing programs.

Reactors described and experiences outlined include Norway's JEEP, France's Sacly reactor, Britain's BEPO and E-443, the U. S.'s water boilers, swimming pools, and closed-tank units, the U. S. S. R.'s H_2O and D_2O models, and a proposed Swiss D_2O reactor.

4—Cross-Sections Important to Reactor Design

This volume contains the proceedings of Geneva sessions 15A, 16A, 17A and 18A which provided some of the conference's most exciting moments

Here, for example, are the papers on the cross sections of fissionable materials that revealed the startling agreement among values obtained by workers in the American, British and Russian atomic energy programs in spite of the secrecy that had applied till then. The best data available to date on delayed neutron periods and abundances are given in the paper of Keepin and Winett. Here, too, is Harvey's analysis of the fundamental cross sections of boron, gold, U^{238} and U^{235}.

Session 15A was devoted to equipment and techniques used in measuring these cross sections. The articles in this section constitute the best compilation to date of time-of-flight techniques for measuring neutron cross sections.

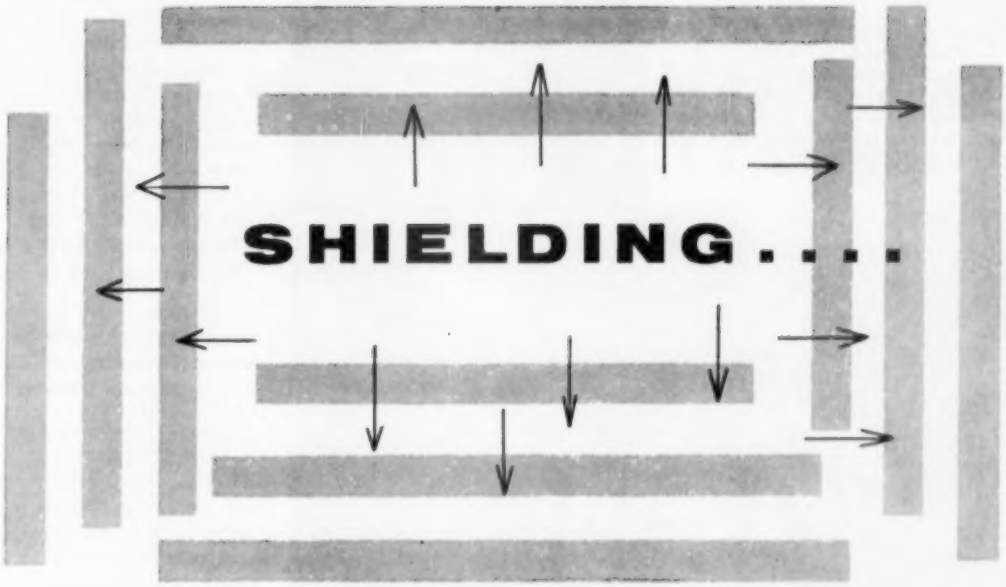
In the section on the further properties of fissionable materials, one finds the Russian data on number of neutrons per neutron absorbed in U^{233} that they alone had. Here too is Hurwitz's excellent review of reactor-materials cross sections pointing up those cross sections and resonance parameters that still need improved values.

The increased interest in measuring fission cross sections that has followed the Geneva conference will in time cause some of the results given in vol. 4 to be outdated. However, for the present they represent the best compilation of experiments and results in that area.

7—Nuclear Chemistry and the Effects of Irradiation

Chemical problems and the stability of reactor materials in the radiation field are the most stubborn remaining obstacles to full-scale development of fission applications.

Volume 7 presents some aspects of these problems: chemistry of the fission products and heavy elements (sessions 8B.1, 8B.2, 9B.1, 9B.2, 10B.1, 10B.2, 10B.3) and effects of radiation on reactor materials, liquids, and solids (11B, 12B, 13B). The papers under-



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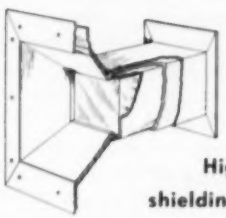

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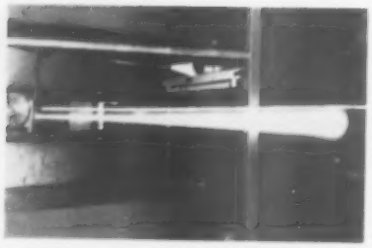
Below is shown the interior of one of NSEC's modern radiochemical laboratories. Photograph (right) was taken of the cyclotron at the Sara Mellon Scaife Radiation Laboratory at the University of Pittsburgh.



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line the vast amount of data yet to be accumulated.

The fission process and chemistry of the fission products are discussed in 25 papers; U. K., U. S. A., and U. S. S. R. hot-laboratory facilities in 6 papers; chemistry of the heavy elements in 27 papers; and the effects of radiation on reactor structural materials and fuel in 9 papers, on liquids in 12 papers, and on solids in 7 papers.

14—General Aspects of the Use of Radioactive Isotopes; Dosimetry

Volume 14 contains the sessions on dosimetry (session 20C) and production and use of isotopes (sessions 7.1 and 19C). Individual papers cover their fields broadly without undue overlap. Users and designers of dosimetry will find important papers on fast and slow neutrons, beta rays, gamma dose, cobalt-60, chemical dosimetry, low-level counting, high-level dosimetry, and various new methods for dose measurement.

About ten of the papers on production and use of isotopes are concerned with the programs that are being followed in different countries of Europe, Asia, and Latin America. The remainder are concerned with specialized techniques such as handling, manipulators, fission products, separators, and industrial uses. Altogether the volume contains 51 papers by authors who are recognized as experts in their fields.

As a record of a significant and rewarding conference, the book will be of great value. One can hope that its handsome format will not conceal the fact that it is primarily a source book, and that future writers can make worthy contributions by condensing and integrating its materials and by filling its gaps.

15—Applications of Radioactive Isotopes and Fission Products in Research and Industry

This volume enters the nuclear field as a wide and general coverage of the uses of radioisotopes in research (session 21C) and control and technology (22C) and fission products and their applications (23C).

The subject range includes tracers, catalysis, activation analysis, autoradiography, gages, bremsstrahlung ap-

plications, wear studies, radiography, food sterilization, nuclear batteries, and beta-excited X-rays.

Countries represented by the authors, in order of the number of papers, are the U.S, U.S.S.R, U.K, Japan, France, Norway, Sweden, Switzerland—the last three with one paper each.

16—Record of the Conference

This round-up volume contains the program of the conference; the complete list of officers, delegations and secretariat members; the rules of procedure; a numerical and an author index of the papers presented; the verbatim transcripts of the opening and closing plenary sessions with their keynote and summary speeches; photographs of some of the technical exhibits; and, perhaps most valuable, the texts of the ten informal evening lectures.

It may be of use, therefore, to list here what may be found in this volume: Niels Bohr on "Physical Science and Man's Position"; Ernest O. Lawrence on "High Current Accelerators"; Vladimir I. Veksler on "Principles of the Acceleration of Charged Particles"; George de Hevesy on "Radioactive Tracers and their Application"; Willard F. Libby on "Radiocarbon Dating"; Hans Bethe on "Light Mesons"; Louis Leprince-Ringuet on "Heavy Mesons and Hyperons"; Alexander Hollaender on "Modification of Radiation Response"; Andrei L. Kursanov on "Radioactive Elements in the Study of Plant Life," and Sir John Cockcroft on "The Future of Atomic Energy."

One regrettable oversight on the part of the editors of the proceedings is their failure to provide a subject index to the 1,132 papers. Such an index, for which the numerical and author indexes are no substitute, would have been an invaluable key and guide to the treasure-house of nuclear data contained in these 16 volumes.

Thermal Power from Nuclear Reactors

By A. STANLEY THOMPSON and OLIVER E. RODGERS (John Wiley & Sons, Inc., New York, and Chapman & Hall, London, 1956, xiii + 229 pages, $7.25).

In organizing the analytical aspects of engineering developmental problems of power reactors, this book attempts to tie together separate viewpoints of

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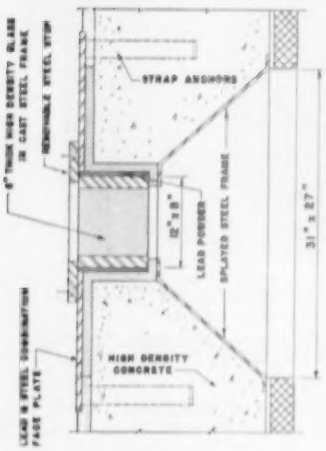

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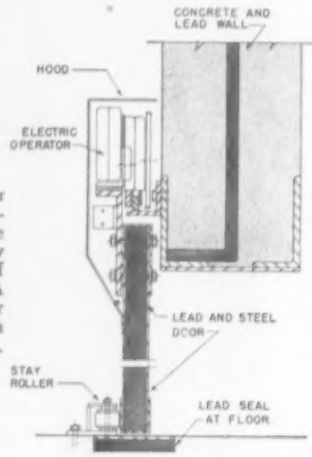

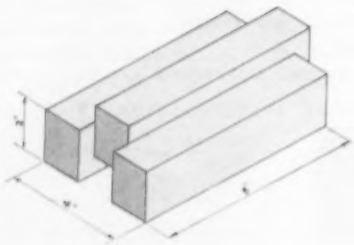

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reactor problems so as to present a unified picture of a reactor. With this objective in mind, it doesn't mention many important nuclear theories (e.g., mechanisms of fission).

Part of the material is based on lectures that one of the authors gave in a course in reactor engineering given at the Oak Ridge School of Reactor Technology in 1952.

The analytical viewpoint is used to relate the unique engineering design problems of nuclear plants to the more familiar ones of conventional power plants. In doing this, the authors begin their treatments with approaches common to engineering practice. They explain that, although some workers in the nuclear field will consider these unconventional, their methods are similar to those that have been found useful in achieving practical solutions to conventional engineering problems.

In emphasizing new methods developed for reactor analysis, the book amply treats numerical methods, dimensional analysis, and nonlinear kinetics of reactors. This same philosophy tends to justify the large amount of space devoted to mathematical treatments of neutron distribution, criticality, and reactor kinetics. These, together with fundamentals and primarily analytical approaches to reactor physics, occupy the first 158 pages. Included in this portion are discussions of shielding and reactor materials. Some methods for shielding calculations are not treated in the belief that better techniques will evolve as a result of shielding experiments.

Power removal is considered under chapters covering thermal stress, power extraction, and thermal cycles. Workers familiar with the nuclear aspects will find these sections a useful introduction to power removal.

The book is important as an approach to analytical procedures for engineering problems of power reactors. Sufficient references are listed to help the reader pursue particular aspects. Unfortunately, the lack of physical explanations of unfamiliar concepts, examples of current reactor practice, "hardware" illustrations, more detailed materials considerations, and numerical examples for the analyses will limit the volume to supplemental status in introducing the power engineer to the nuclear field. Generally, the same kinds of limitations restrict the book's usefulness in familiarizing the nuclear engineer with the status of the power field.

Nuclear Magnetic Resonance

By E. R. ANDREW (Cambridge University Press, New York, 1955, xi + 260 pages, $6.50). Reviewed by NORMAN F. RAMSEY, Harvard University, Cambridge, Mass.

Professor Andrew's new book is excellent in almost every way. The book is a valuable contribution to the new and important field of nuclear magnetic resonance in bulk matter.

In his introductory chapter, Professor Andrew discusses magnetic properties of nuclei, nuclear paramagnetism, and nuclear magnetic resonance in bulk matter. In Chapter 2 he discusses the basic theory of nuclear-magnetic-resonance experiments, including theories of relaxation times, saturation, magnetic susceptibility, resonance absorption, and nuclear induction.

The third chapter of the book provides an excellent summary of the various experimental methods for studying nuclear magnetic resonance, including bridge circuits, super-regenerative methods, nuclear induction, pulse methods, optical methods, etc. A discussion of magnets and of signal-to-noise ratios is also contained in this chapter.

The fourth chapter discusses applications of nuclear resonance methods to the measurement of such nuclear properties as spins, signs of magnetic moments, magnitudes of magnetic moments, electric quadrupole moments, etc.

The fifth chapter discusses nuclear magnetic resonance in liquids and gases. Theoretical and experimental studies of spin-lattice relaxation resonance line widths, chemical shifts, and electron-coupled nuclear spin-spin interactions are included.

In Chapter 6 Professor Andrew discusses nuclear magnetic resonance in nonmetallic solids. His own field of research is chiefly related to the subject of this chapter. As a result the treatment of this subject is especially good and detailed. The topics in this chapter include resonance absorption spectra for rigid structures, Van Vleck's second-moment formula, structural studies, hindered rotations in solids, self-diffusion in solids, etc.

The seventh chapter is concerned with nuclear magnetic resonance in metals, including spin-lattice relaxation times and shifts of metallic nuclear resonance frequencies. The final chapter of the book contains a discussion of nuclear quadrupole effects in solids, liquids, and gases.

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By C. ROGERS MCCULLOUGH, *Monsanto Chemical Co.*

NUCLEAR RADIATION IN FOOD AND AGRICULTURE

By RALPH SINGLETON, *Univ. of Virginia*

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discussed clearly and in moderate detail. Unfortunately, the limited space available makes it necessary for the author frequently to quote theoretical results without giving the detailed derivations. This is particularly true of the discussions of nuclear quadrupole interactions. Also, in view of the importance of the applications to chemical analysis, it is unfortunate that Professor Andrew did not give a more detailed discussion of chemical shifts, electron-coupled nuclear spin-spin interactions, and the applications of these shifts to chemical analysis.

Professor Andrew provides several useful tables of references that indicate which scientists have studied the various nuclei and chemical compounds. Unfortunately, these tables include none of the experimental results. In some respects this is an advantage since it encourages the reader to study the original papers. On the other hand this advantage is more than off-set by the inconvenience to the reader from the absence of all tables of numerical results of past experiments.

Andrew's "Nuclear Magnetic Resonance" should certainly be added to the library of all present and prospective research scientists in this field. It would also provide a suitable text book for a course on nuclear magnetic resonance. The book is well written and covers the currently active research field of nuclear magnetic resonance of bulk matter in greater detail than any other book at present available in this specific field.

BOOKS RECEIVED

Radiation Biology. Vol. 3—Visible and Near-Visible Light, edited by Alexander Hollaender (McGraw-Hill Book Co., Inc., New York, 1956, viii + 765 pages, $10.00). *(To be reviewed.)*

Lectures on Theoretical Physics. Vol. 5—Thermodynamics and Statistical Mechanics, by Arnold Sommerfeld (Academic Press, Inc., New York, 1956, vii + 401 pages, $7.00). This book, in preparation at the time of Sommerfeld's death, was completed by F. Bopp and J. Meixner. The translation is by J. Kestin. Beginning with thermodynamics and its application to special systems, the author then introduces statistical mechanics with the kinetic theory of gases. He considered the high point of the book the next section on Boltzmann's com-

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binatorial method of statistical mechanics. He concludes with the dynamic method based on Boltzmann's collision equation.

Electronics, Waves, and Messages, by John R. Pierce (Hanover House, Garden City, N. Y., 1956, 318 pages, $5.00). This book authoritatively, but simply, explains the theory, applications, and problems of electronics.

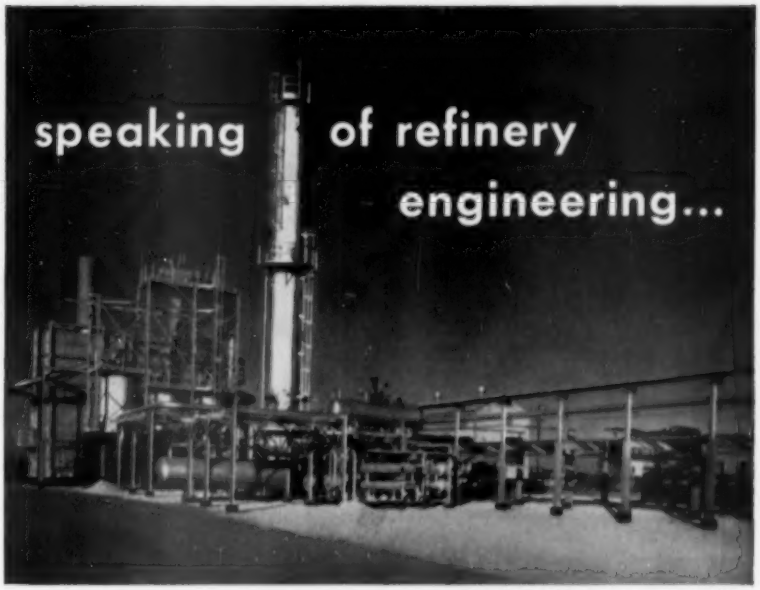
The Meaning of Relativity, 5th ed., by Albert Einstein (Princeton University Press, Princeton, 1956, 166 pages, $3.75). Appendix 2 of the fifth edition contains Einstein's revision of his Generalized Theory of Gravitation under the title "Relativistic Theory of the Non-symmetric Field." By simplifying the derivations and form of the field equations, "the theory becomes thereby more transparent, without changing its content."

Network Analysis, by M. E. Van Valkenburg (Prentice-Hall, Inc., New York, 1955, vii + 440 pages, $13.00). The reader is introduced to the study of electric networks by the pole and zero approach. Applications to reactive networks, stagger-tuned amplifier-networks, and feedback systems are considered.

ALSO OF NOTE

Monte Carlo Reactor Calculation. This report (PB 111865), by S. Podgor and L. A. Beach of the Naval Research Laboratory Radiation Division, covers the use of the Monte Carlo method to estimate the slowing down of fast neutrons in a spherical homogeneous mixture of U^{235} and H_2O. The estimated probability distribution of thermalization compared favorably with those of other calculation methods and with experimental measurements. These probability distributions were used to calculate the critical ratio of U^{235} to H_2O for bare and reflected core reactors. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., $0.50.*

Correction: The book incorrectly listed as "Electronics and Electron Physics," Vol. 7 (NU, March '56, p. 103) should have been listed as "Advances in Electronics and Electron Physics," vol. 7, edited by L. Marton (Academic Press, Inc., New York, 1955, x + 527 pages, $11.50).



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Teletherapy Installations

Versatility in complete teletherapy installations is available by combining available heads and several different mountings. Convertron head (at left) is designed for Cs^{137} treatments. Shielding reduces dose rate when closed to 6.25 mr/hr at 5 cm from 5,000 curies. Internally mounted light source shows definition of beam that can be adjusted by a diaphragm up to 20 × 20 cm at 25 cm. At face of instrument, dose rate outside beam limits is everywhere <0.25% of axial dose. The head in figure at right has similar properties when loaded with 2,000 curies of Co^{60}.

Stabilatron mounting (right) allows motorized positioning of head from mobile pedestal, and is designed for static and multiple-port therapy. Mobaltron supports head from free-standing vertical pillar and permits rotation therapy. Also available is telescopic ceiling suspension.

Remote control desk has timer, clock, interlock indicators, stop and emergency buttons, and colored lights to indicate conditions of power on, source moving, adjustments completed, and source exposed.—Nuclear Engineering Ltd., London S. E. 7, England.

PIPING COMPONENTS

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The first two-stage canned motor pump, this 3-hp Chempump gives heads to 230 ft. Standard temperature and pressure limits are 450° F and 300 psi. The pump is available in cast iron, cast steel, 300-series stainless steel, Monel, and Carpenter-20.—Chempump Corp., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Piping. Pipe insulation jacketing of preformed polyethylene is simple to install, can be fastened at longitudinal seams with staples, is reuseable.—Pip-Jac Co., 295 Beverly Rd., Pittsburgh 16, Pa.

ELECTRONIC INSTRUMENTS AND APPARATUS

Variable delay line. The new 1-μsec Helidel variable-delay line has delay adjustable in increments of 0.04 mμsec. Rise time is 0.08 μsec max.; frequency response is 0–4.5 Mc. The Helidel is a 10-turn unit, with mechanical rotation of 3,600 deg (+5, −0)—Helipot Corp., 916 Meridian Ave., South Pasadena, Cal.

Coaxial cable. New microminiature coaxial cable has capacitance of 12 μμf/ft, o.d. of 0.132 in. maximum. Its impedance is 98 ohms; velocity of propagation, 80%; temperature rating −65° to +120° F.—Microdot, 1826 Fremont Ave., South Pasadena, Cal.

D-C Power Transformers

D-C to d-c semiconductor power transformers are available in miniature, standard, and high-power series, ranging from ¾ watt to 1 kw. Models now available produce up to 3,000 volts, and can be designed for up to several thousand volts. Device employs special semiconductor heating elements that generate square wave from a d-c source. Conversion efficiencies up to 90% are claimed. Input voltages are from 1.5 to 60 volts. Voltage regulation is available to 0.1%. No moving parts.—Intercelectronics Corp., 2432 Grand Concourse, New York 58, N. Y.

•

Transistor production. "Grown-diffused" technique for producing transistors is said to work with both germanium and silicon. It produces transistors that will amplify at usable power levels to over 100 Mc and oscillate to over 250 Mc.—Texas Instruments, Inc., 6000 Lemmon Ave., Dallas 9, Tex.

Silicon diodes. Produced in production quantities, silicon power-junction diodes are said to operate from −55° C to 200° C. Peak reverse voltage is from 50 volts to more than 400. Typical reverse resistance is said to be greater than 1 megohm at temperatures up to 125° C. Specially selected slow-leakage diodes are available with reverse resistance in the range of 1,000 megohms at 25° C.—International Rectifier Corp., 6809 S. Victoria Ave., Los Angeles 43, Cal.

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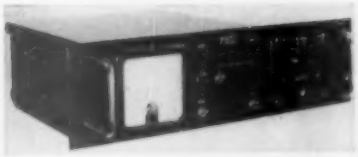
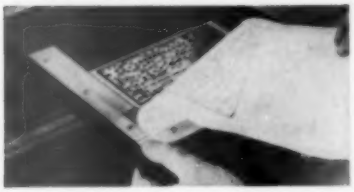


Micro-Microammeter

Type-ND-11 is intended for ionization-chamber-current measurement in process-plant conditions. It uses electrometer triode to measure current in six ranges of from 10^{-11} to 10^{-6} amps full scale. Contains voltage source for ion chambers.—Elliott Bros., Ltd., Century Port, Lewisham, S. E. 13, England.



Printed Circuits

Preparation of printed electrical circuits for etching can now be done by "xerography." This is described as a fast, dry, electrostatic method of copying, heretofore used chiefly in office and graphic arts reproduction. From an original opaque drawing a copperclad laminate serving as a printed circuit or wiring board can be prepared for etching in about 10 min. Process is said to be about nine times faster than other processes in common use, for the first circuit.—The Haloid Co., Rochester 3, N. Y.

Resistor

Miniature high megohm resistor is hermetically sealed in glazed steatite jacket. The resistor has low voltage and temperature coefficients, and max. voltage of 2,500.—Resistance Products Co., 914 S. 13 St., Harrisburg, Pa.

Delay system. Model V-124 delay system has two 0–10 sec variable delay lines, variable in decade steps of 1 and 0.1 μsec and fine control of 0 to 0.1 μsec with infinite resolution. Impedance is 1,000 ohms.—Control Electronics Co., Inc., 1925 New York Ave., Huntington Station, N. Y.

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Trimmer potentiometer. Made of a precious-metal-film resistance element, tiny trimmer potentiometer is said to provide infinite resolution through 28½ turn adjustment. Units are available with resistance from 50 to 25,000 ohms with 5% linearity and able to operate from −57° C to 125° C. Size is $1\frac{1}{32} \times \frac{13}{32} \times 1\frac{21}{64}$ in.—Fairchild Controls Corp., 6111 E. Washington Blvd., Los Angeles 22, Cal., or 225 Park Ave., Hicksville, N. Y.

Preamplifier. New oscilloscope preamplifier uses principle of "hushed transistor operation," and has less than 1 μv rms noise over a frequency band of 60 kc. Additional amplification is provided by vacuum tubes.—Volkers & Schaffer Mfg. Corp., Box 996, Schenectady, N. Y.

Direct-coupled amplifier. New amplifier for driving low-impedance loads features full-scale output of ±40 ma into a 35-ohm load with ±60-mv input; output impedance loads from 0 to 1,000 ohms; flat frequency response from 0 to 50,000 cps; and linearity within 1%.— Photocon Research Products, 421 N. Foothill Blvd., Pasadena, Cal.

Oscilloscope. Oscilloscope with type 53K/54K preamplifier has vertical-amplifier risetime of 12 mμsec and passband of d-c to 30 Mc at calibrated sensitivities from 0.05 to 20 v/cm, with 20 μμf input capacitance direct, 7.5 μμf with 10× probe. —Tektronix, Inc., P. O. Box 831, Portland 7, Ore.

Shielded tube caps. Skirted corona-shielded tube cap was designed for use on RCA VR tube 6BK4, can be used in any circuit where that tube is used and with other glass tubes having similar dimensions and a $\frac{9}{16}$-in. cap. The corona-shielding tube cap with in-line resistor accomodates anything up to a 2-watt resistor. Both tube caps have contact, lead, and corona shield assembly molded as integral inset into the insulating body.—Alden Products, Brockton, Mass.

Relay. Said to be the first relay to incorporate thorough wiping action with 10 mw per contact, new Model 100-C has coil resistance up to 30,000 ohms, contact capacity up to 1 amp inductive and 3 amp resistive load. Relay is available hermetically sealed or with dust cover in contact combinations from SPST to DPDT.—Hedin Tele-Technical Corp., 640 W. Mt. Pleasant Ave., Livingston, N. J.

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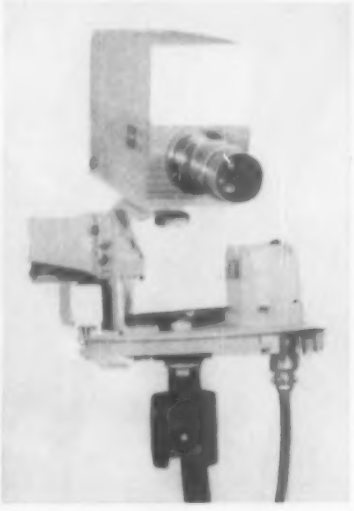

Industrial Television

Model-1985 is a closed-circuit industrial television with removable plug-in subassembly construction. Camera (above) weighs less than 5 lb. System consists of camera control and monitor, which can be had in 10 in., 17 in., or 21 in. sizes. Sync generator provides full count, 525 lines, 2:1 interlaced operation. Accessories include remote pan and tilt, lens-control mechanism, remote three-lens turret, explosion-proof, weatherproof, and underwater housing, as well as remote monitor.—Kay Lab, 5725 Kearney Villa Rd., San Diego 12, Cal.

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Gas flow calibrator. Dual-range gas-flow standard uses two meter elements, each having reproducibility of better than 0.1% of full scale with guaranteed accuracy of 0.25% of full-scale flow. Measurements of flow over a 13/1 range is better than 1% of indicated flow; over a 33/1 range, better than 2½%.—National Instrument Laboratories, Inc., 6108 Rhode Island Ave., Riverdale, Md.

Variable-speed-motor drive. New Thyratron speed control allows constant full-load torque on d-c motors from 10 to 50 hp. It has 10 to 1 ratio.—Ther Electric Works, Dept. NUD, 17 S. Jefferson St., Chicago 6, Ill.

Solid-state battery. This water-free battery has an expected shelf life of up to 10 years. A unit of 1-in.^{3} volume can give an output of 200 volts.—P. R. Mallory & Co., Inc., Battery Div., North Tarrytown, N. Y.

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Low-temperature cabinets. Horizontal storage cabinets for temperatures to −120° F. are available in 3-, 6-, and 9-ft.^{3} capacity; vertical cabinets are available in sizes 22- and 24-ft.^{3}, with temperatures of −10°, −40°, −60°, −90°, and −120° F. All models use Freon.—Labline, Inc., Chicago Surgical and Electrical Co., 3070–82 W. Grand Ave., Chicago 22, Ill.

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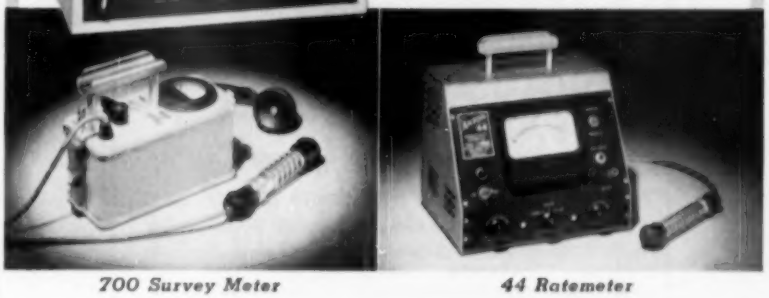

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Green-yellow slide rule. Green-yellow slide rule eliminates glare. Available in trig, log-log standard, or special rules, they are made of light alloy, are guaranteed accurate to 7 decimals.—Pickett & Eckel, Inc., 1109 S. Fremont, Alhambra, Cal.

Quick-connect valve. New quick-connect vacuum valve permits connecting and opening an assembly to a vacuum-pumping or gas-filling system in less than 10 sec; permits valving-off and disconnecting assembly from system, without loss of vacuum or gas, in another 10 sec.—NRC Equipment Div., National Research Corp., Newton Highlands 61, Mass.

Self-focusing CRT. The 1CP1 features automatic self-focusing at low anode voltage from 500 to 1,500 volts and has 250-volt heater-cathode insulation.—Beam Instruments Corp., 350 Fifth Ave., New York 1, N. Y.

Metal filter. New sintered-metal filter can remove particles as small as 1 micron in dia, and handles fluids with temperatures up to 1,000° F.—Purolator Products, Inc., Rahway, N. J.

RADIATION DETECTORS AND ACCESSORIES

Chromatograph Scanner

Chromatograph scanner shown uses small flow counter with low background, scans strips up to 1½ in. in width, of any length. It can be used with or without window. Without window, scanner is said to be particularly good for work with low-energy beta rays. Its 2π geometry insures high efficiency. Contaminated windows can be exchanged in a few seconds; scanning head can be quickly decontaminated.—Forro Scientific Co., 833 Lincoln St., Evanston, Ill.

•

Pulse generator. Model-340 generates four square pulses of 1-mμs rise time, widths from 0.001–0.1 μs. Four outputs independently variable in amplitude.—Electrical & Physical Instruments Corp., 25 W. 43rd St., New York 36, N. Y.

High-level dosimetry. Plastic film for measurement of electromagnetic and particulate radiation in the range 0.2–10 × 10^6 r is available (NU, Sept. '54, p. 62). Film reading service or calibration curves are offered.—Radiation Applications, Inc., 342 Madison Avenue, New York 17, N. Y.

Pulse generator. Model B-3 pulse generator is designed for applications involving repetition rates to 1 Mc, delays from 0 to 10,000 μs, and fast-rise positive or negative pulses with widths to 10,000 μs. Pulse width can be continuous or varied 0.08–10,000 μs in five ranges. Rise time of main pulse is less than .02 μs, but it may be degraded to 1 μs by front-panel control. Output impedance is 50 ohms. —Rutherford Electronics Co., 3707 S. Robertson Blvd., Culver City, Cal.

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Spectrometer

New spectrometer (shown) features single-channel analyzer that permits counting any particular energy peak with exclusion of background and secondary emissions outside the limits of the channel width setting. Scintillation probe has 1-in. lead shield on all sides of the crystal; a 2-in. non-activated NaI crystal is used for light pipe between activated crystal and photomultiplier. Focusing collimeter provides focal point 1.9 in. in front of nose; at focal point 50% radiation contour line is 0.38 in. wide; 100% contour line is half that.—Detectolab, Inc., 6544 N. Sheridan Rd., Chicago 26, Ill.

Metal-Walled Counter Tube

New G-M counter tubes are constructed entirely of metal except for a glass bead insulator. The brass cylinder, used as both envelope and cathode, provides strength, resistance to shock, and simplicity of design. Tubes are available with glass bead insulators on one or both ends. Active length varies from 3 to 40 in.; starting voltage from 870 ± 30 to 1,130 ± 50; plateau from 150 to 200 volts; and plateau slope (per 100 v) from 5 to 10%.—H. W. Leighton Laboratories, York Rd. and Sunset Lane, Hatboro, Pa.

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Portable scintillation counter. New well-type scintillation counter is portable; its shield is made of 2-in.-high interlocking rings.—Atomic Center, Inc., 489 Fifth Ave., New York 17, N. Y.

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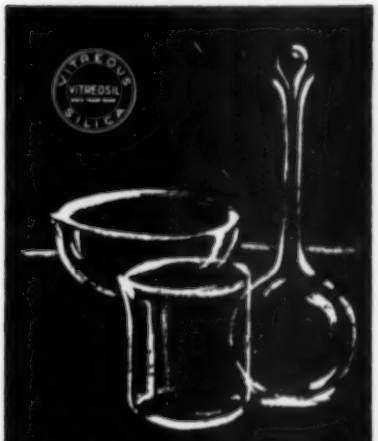
Gamma Spectrometer. Model 1810 offers gamma-ray pulse-height analysis. Single battery unit contains single-channel pulse-height analyzer to be used with any laboratory scaler or ratemeter having a high-voltage power supply and an input sensitivity of less than 10 volts. Window is adjustable from 0 to 10 volts.—Nuclear-Chicago, 331 W. Erie St., Chicago 10, Ill.

Flow Counter

Flow proportional counter has counting rate exceeding 60,000 cps for fast radiation. It is said to detect all elements down to and including magnesium. Device is designed for use with manufacturer's x-ray spectrograph and helium attachment when latter is required.—North American Phillips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Condenser R-meter. Revised model-572570 operates on 110 volts, 50–60 cps a-c. Uses same chambers as model 70.—Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, O.



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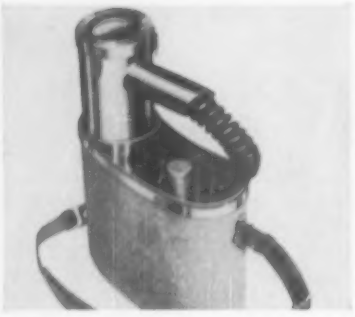

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LITERATURE AVAILABLE

Nondestructive testing. Techniques and equipment are described in portfolio of brochures and leaflets.—Solus-Schall Ltd., 18/22 New Cavendish St., London, W. 1.

Nuclear instruments. Price list covers variety of nuclear equipment. 2 p.—Radiation Counter Laboratories, Inc., 5122 W. Grove St., Nucleonic Park, Skokie, Ill.

Waste treatment. Technical discussion of several processes for treatment of industrial waste. 6 p.—Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18.

Flow of fluids. Alternating flow of fluids in tubes is discussed in technical paper. 8 p.—Stratham Laboratories, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Cal.

Plotters. X-Y plotters and input accessories for graphic depiction of one independent variable in terms of another are described. 8 p.—Librascope, Inc., 808 Western Ave., Glendale, Cal.

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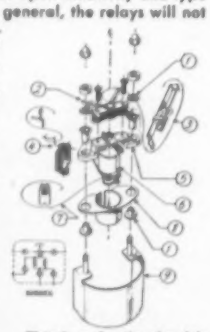

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Resistance-thermometer elements. Four-page folder describes tiny RdF Stikon, resistance-thermometer elements intended for surface-temperature measurement and control.—Arthur C. Ruge, 733 Concord Ave., Cambridge 38, Mass.

Ceramics. Facilities and ceramic products of the firm are described in new brochure.—12 p.—Raytheon Manufacturing Co., Waltham 54, Mass.

Rare earths. Catalog-price list contains description and typical analysis of cerium, rare earth, and thorium chemicals, and data on the firm. 40 p.—Lindsay Chemical Co., West Chicago, Ill.

Nuclear medical laboratory. Data file 140 is a handbook for planning nuclear medical programs. It includes advice on instrumentation, outlines AEC recommendations, explains committee organization for institutional radioisotope programs and training requirements for individual practice.—Dept. EE34, Berkeley Div., Beckman Instruments, Inc., 2200 Wright Ave., Richmond 3, Cal.

Accidental discoveries. The stories of 20 accidental scientific discoveries, from X-rays to the benzine ring, are told in 64-page booklet.—Schaar and Co., 754 W. Lexington St., Chicago 7, Ill.

Ore analyzer. A new instrument for determining uranium and thorium content is described in 4-page bulletin.—Tracerlab, Inc., 130 High St., Boston 10, Mass.

Hoses. Flexaust hoses and Portovent ducts are described in new price list folder.—The Flexaust Co., 100 Park Ave., New York 17, N. Y.

High temperature bath. New leaflet provides data on high-temperature aging bath, for water or oil. 2 p.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

Metal fabrication. Facilities and processes for fabricating alloy sheet and light plate are graphically described in new brochure. 32 p.—S. Blickman, Inc., Weehawken, N. J.

Thermocouple insulating tubing. Details of thermocouple refractory insulators are given in 6-page bulletin.—Stupakoff Div., The Carborundum Co., Latrobe, Pa.

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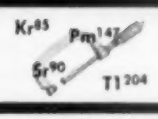

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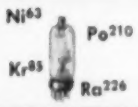

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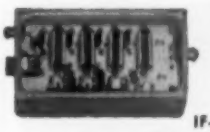

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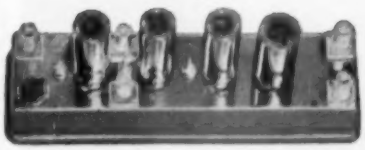

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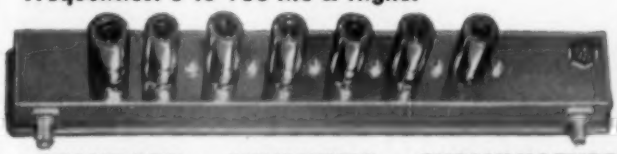

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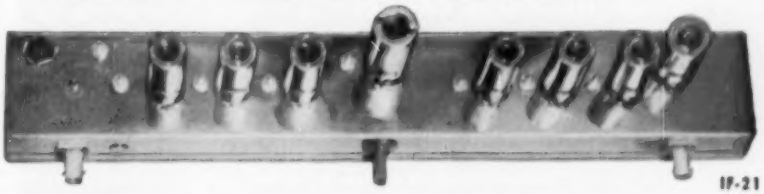

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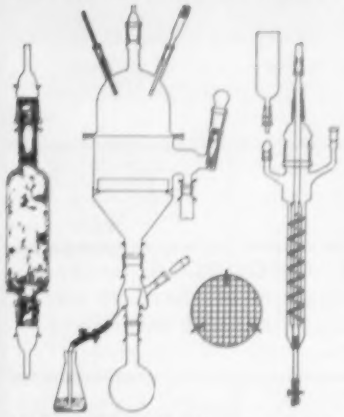

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Ceramics. Physical and electrical characteristics, other data on 11 ceramic materials are detailed in new booklet. 6 p. Stupakoff Div. of The Carborundum Co., Latrobe, Pa.

Isotope scanner. The 8th issue of "The Nucleus" describes new isotope scanner. 4 p.—Nuclear-Chicago, 299 W. Erie St., Chicago 10, Ill.

Betatron. The 31-Mev Betatron and its application in deep therapy, industrial radiography, and atomic research are discussed in detail in new publication. 52 p.—Brown Boveri Corp., 19 Rector St., New York 6, N. Y.

Humidity recorders. New bulletin describes portable recorders for relative humidity and temperature. 4 p. —The Bristol Co., Waterbury 20, Conn.

Product literature directory. New directory contains alphabetical description of Allis-Chalmers products and literature, and lists the firm's plants, sales offices, and tractor branch houses. 24 p.—Allis-Chalmers Manufacturing Co., Milwaukee 1, Wis.

Speed reducers. Full information on complete line of speed reducers is contained in new 52-page bulletin.—Farrel-Birmingham Co., Inc., Ansonia, Conn.

Comparator Gage. New 4-page bulletin describes all-purpose comparator gage, which has four ranges.—Metron Instrument Co., 432 Lincoln St., Denver 3, Col.

Rotary airlock feeders. Specifications, dimensional drawings, and descriptions of rotary airlock feeders are contained in 12-page catalog.—Prater Pulverizer Co., Chicago 50.

Heating controls. Automatic time controls for use with oil burners, gas units, and stokers are described in 4-page folder.—International Register Co., 2620 W. Washington Blvd., Chicago 12, Ill.

Conductive coatings. Manual M31 discusses electrically conductive coatings. 9 p.—Micro-Circuits Co., New Buffalo, Mich.

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Laboratory glassware. Revised catalog covers 6,000 special Pyrex glass items, including 50 listed for first time. 139 p.—Laboratory and Pharmaceutical Sales Dept., Corning Glass Works, Corning, N. Y.

Power supplies. Condensed standard specifications on power supplies, voltage regulators, frequency changers, etc. are contained in new 4-page catalog.—Sorenson and Co., Stamford, Conn.

Multiple V-belt drive. History, development, and engineering of V-belt drives are discussed in a new 64-page booklet.—Allis-Chalmers Manufacturing Co., 1316 S. 70 St., Milwaukee, Wis.

Steels. A new catalog gives detailed information on alloy and stainless steels for process and manufacturing industries. 102 p.—Electric Steel Foundry Co., 2141 N. W. 25 Ave., Portland 10, Ore.

Voltmeters. Expanded scale a-c voltmeters for panel mounting are described in 4-page folder.—Arga Div., Beckman Instruments, Inc., South Pasadena, Cal.

Lubricated plug valves. New, indexed catalog describes complete line of iron and steel lubricated plug valves. Bodies of Powell valves are of cast carbon steel; plugs of hardened chrome-nickel-moly-steel; other alloy plug valves are available on special order. 36 p.—The Wm. Powell Co., Cincinnati 22.

Fuel elements. Two-page folder describes facilities for fabrication of fuel elements and fuel element components for reactors.—Metals and Controls Corp., Nuclear Products Div., Attleboro, Mass.

Precious metals. The operations and capabilities of General Plate in manufacturing materials of precious and composite metals are described in 12-page brochure.—Metals and Controls Corp., General Plate Div., Attleboro, Mass.

Partitioner. Data on first commercial instrument to make full use of potentialities of gas-liquid partition chromatography are given in 8-page brochure.—Fisher Scientific, 711 Forbes St., Pittsburgh 19, Pa.

Water stills. New catalog provides comprehensive data on Barnstead water stills. 48 p.—Barnstead Still & Sterilizer Co., Boston 31, Mass.

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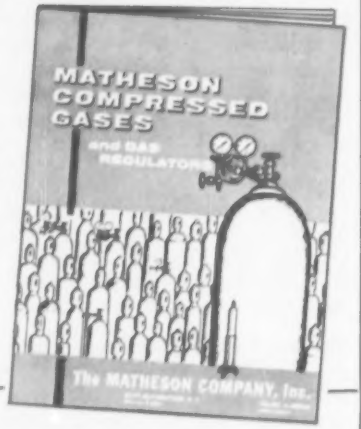

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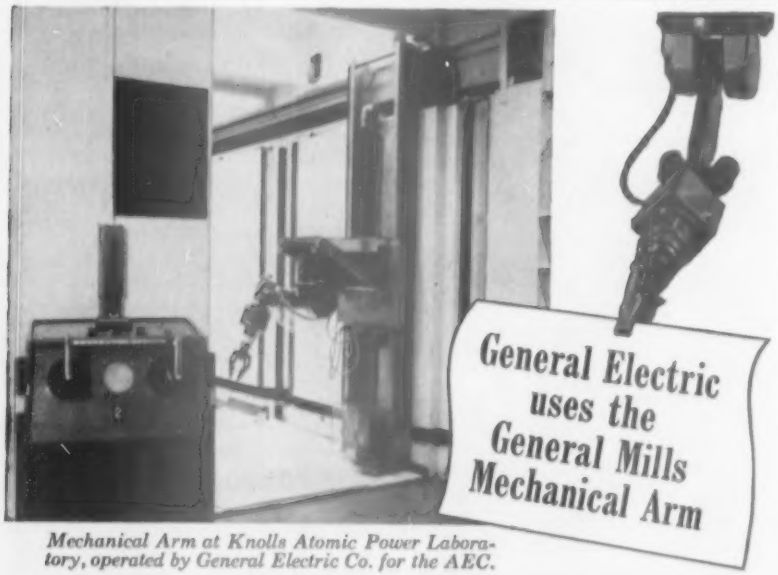

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Process industries. The work of Blaw-Knox in 17 process industries, including nuclear energy and special development, is pictured in a new 20-page catalog.—Chemical Plants Div., Blaw-Knox Co., Pittsburg, Pa.

Portable ammeters and voltmeters. A new catalog sheet describes and gives specifications for portable, self-contained ammeters and voltmeters. —Phaostron Instrument and Electronic Co., 151 Pasadena Ave., South Pasadena, Cal.

Visible grinding. Brochure describes grinding method that permits operator to see through grinding wheel. 4 p.—Carl Hirschmann Co., Inc., 30 Park Ave., Manhasset, New York.

Radiation shielding. Doors, windows, high-density concrete bricks, lead bricks, isotope hoods, and lead containers are described in 4-page folder.—Ray Proof Corp., 513 W. 54 St., New York 19, N. Y.

INDUSTRY NOTES

▶**Nicholas E. Anton** remains president of the company as the **Anton Electronic Laboratories, Inc.**, Brooklyn, N. Y. are acquired by the **U. S. Hoffman Machinery Corp.**, New York.

▶**John Rothamel** has joined the staff of **Tracerlab's** New York office, which will now handle maintenance and service on the company's instruments.

▶**Dalic Metachemical Ltd.** of Toronto, Canada, has appointed **Marlane Development Co.**, 153 E. 26 St., New York, as a distributor for the Dalic Process of electroplating.

▶**Resistoflex Corp**, producer of high-temperature, high-pressure hose products, has doubled its capacity by the occupancy of a new plant and research facility at Roseland, N. J.

▶Hart high pressure equipment, manufactured in Holland, is now distributed in the United States, Alaska, Hawaii and Puerto Rico by the **Research and Instruments Div. of North American Phillips Co.**

▶**William Waits**, formerly with Philco, has been appointed regional sales manager for **NRD Instrument Company's** new southeastern area, with offices in Atlanta, Georgia.

▶**Herman H. Rappaport,** formerly engineering construction manager of factory construction for **McDonald Brothers,** has formed the **Rappaport Construction Company** with temporary headquarters in Torrance, Cal.

▶**Donald Q. Kern** has formed the **D.Q. Associates,** with offices at 7016 Euclid Ave., Cleveland 3, Ohio, and branches in New York and Washington. Five associates are prominent in the fields of nuclear engineering, high-pressure techniques, distillation, heat transfer, and thermodynamics. The firm specializes in thermal-process technology.

▶**Instrument Development Laboratories** has appointed **Fred H. Gerring** as manager, customer relations, to handle federal sales. Gerring was formerly technical advisor on stabilization of missiles in the Bureau of Aeronautics, Navy Department, in Washington, D. C.

▶**William B. Johnson & Associates** have established a new sales office and service facilities at 126 Liberty St., New York 6, N. Y., to handle their own products as well as those of **Radiation Counter Laboratories, Forma Scientific Co., Blue M. Electric Co.,** and **Landsverk Electrometer.**

▶**The Martin Co.,** St. Louis, will handle national advertising and public relations for **NRD Instrument Co.** and **Nuclear Consultants, Inc.,** both of St. Louis. These two firms recently became divisions of **Nuclear Corporation of America,** New York.

▶**Sorensen & Co., Inc.,** Stamford, Conn., manufacturers of power supplies and regulators, announce the opening of a sales office at 1548 N. Highland Ave., Route No. 5, Hollywood 28, Cal. **Julian M. Polis** is in charge of the new office.

▶**Heavy Minerals Co., Inc.,** is a new jointly owned enterprise of **Crane Co.** and **Vitro Corp.** for production of thorium, rare earth and heavy minerals from monazite, as well as rutile, ilmenite, zircon, and kyanite. **Frank F. Elliott** is chairman of the board.

▶New appointments to the **Automatic Controls Div.** of the **Ferry Corp., Los Angeles,** are as follows: **Benjamin O. Hannesina,** assistant manager; **Jay Borden,** chief engineer; **James Garner,** chief production engineer.

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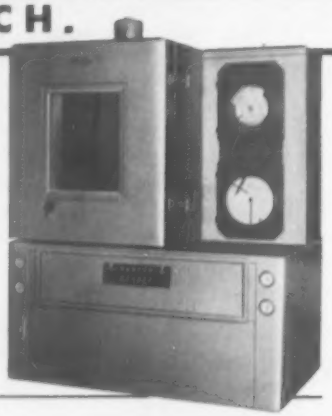

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LETTERS

Indian Power Reactor

DEAR SIR:

I have been informed that a report has appeared in the February 1956 issue of NUCLEONICS (p. 15) to the effect that a decision has been taken to place India's first power reactor at Ahmedabad. This report was presumably taken from similar reports which appeared in the Indian newspapers some time ago. The reports are without foundation and no such decision has been taken.

—H. J. BHABHA
Secretary to the Government of India
Department of Atomic Energy

"Hot" Shipment Containers

DEAR SIR:

Certain difficulties and hazards are encountered in unloading containers of up to 1-curie activity routinely received by the small and medium-sized radioisotope laboratory from secondary suppliers and the AEC Isotope Div.

The purpose of isotope container design is essentially twofold: (1) The material must pass through the ordinary transit channels without disaster. (2) The container must fill the minimum requirements of law. Generally, all shipments fill these criteria.

A third consideration, is occasionally overlooked—a trouble-free and simple disassembly of the packing. The Isotopes Div. has taken some farsighted steps towards obviating such problems. But even they have not completely solved the difficulties.

Disassembly Difficulties

Some common problems are:

Change of an established interior pack without notice or instruction. Besides nullifying preparative work, this necessitates last-minute changes.

Container types that are hard to open remotely. Occasionally the packing is designed for ease of assembly and only secondary consideration given to disassembly procedures. Such dismantling may incur unnecessary dosage.

Lack of detailed information on interior container design. This is related to the first one, but incorporates a hazard when one of a series is opened for the first time. The AEC includes such routine instructions.

Damaged or inadequate "special tools." Returnable, included devices are often unusable because of damage.

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Los Angeles 34, Calif.

Poor health-physics design for disassembly operator. An example is the frequently encountered, unshielded, threaded cap positioned within a well shield, in intimate contact over a source, which necessitates 12–15 360-deg turns for loosening. Unless very special remote equipment is available, the operator's hands are exposed. The small laboratory ordinarily cannot provide such devices.

Transit damage (frequently found in lead shielding). Most workers have inadvertently lifted a hot container out of its surrounding shield when removing a transit-damaged lead shield top. Some shielding demands major repair prior to disassembly. Such incidents, resulting from poor shield design, cannot be predicted.

Sterilized shipments. Combined sterile and health physics procedures (complex in themselves) offer knotty problems when compounded with poor container disassembly design.

Other points include previously contaminated container interiors, threaded assemblies lacking locking devices, etc.

Recommendations

Suggestions for improvement are:

Standardized packing procedures for step-wise activity increments.

Simplified container design for ease of unpacking and operator safety.

Use of simple locks (i.e., bayonet), elimination of threaded parts—particularly right over unshielded hot parts.

Foolproof and accident-proof packing assembly and good lead shield design that will not become dismantled or distorted in transit.

A small, nonreturnable lead core shield for returnable containers.

Elimination of the need for "special tools" or elaborate remote control for disassembly in the small laboratory.

A continuous system of inspection and repair by the supplier of "returnable containers."

Noncorroding moving parts.

It may be useful for a small group of interested recipients to draw up suggestions for changes in packaging techniques.

This note is not a criticism of any particular packaging method or supplier but rather a preliminary step towards improving the communication between recipient and sender of radioactive isotopes.

—L. E. Preuss

Isotope Laboratory, Physics Department
Edsel B. Ford Institute for Medical Research
Detroit, Michigan

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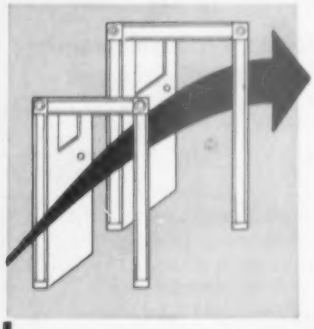

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NEWSMAKERS

AEC appointed **Bryan F. LaPlante** special assistant to the General Manager in charge of AEC's Congressional liaison, succeeding **William C. Wampler,** resigned.

William M. Breazeale left Penn State to join Babcock & Wilcox's Atomic Energy Division. B&W has also acquired **Frank R. Ward,** formerly technical assistant to the manager of the Large Ship Reactor project at Westinghouse.

Henry C. Ott, assistant chief of AEC's civilian power reactors branch, and **Julius M. Simmons,** assistant director of metallurgy at Argonne National Lab, have joined Ebasco Services Inc. as nuclear engineers.

General Electric has named **Ralph D. Bennett,** former manager of the technical department at Knolls Atomic Power Lab, to be manager of the Vallecitos Atomic Laboratory, as GE is designating the new lab it is building at Pleasanton, Calif., near the new San Jose headquarters of its Atomic Power Equipment Department. APED will have **George White,** former Vitro director and v-p, as general manager, replacing **Vice Admiral Willard A. Kitts 3rd,** who will do an APED planning study. **Lester Kornblith, Jr.,** becomes reactor supervisor of the boiling-reactor project at Vallecitos. GE also placed **R. L. Carlson** in charge of surplus, salvage, and scrap sale at Hanford, a $2-million/yr operation.

The National Bureau of Standards has named **Lewis M. Branscomb,** acting chief, to be chief of the atomic physics section; and **James I. Hoffman** to head the metallurgy division succeeding **John G. Thompson,** retired.

Leonard Reiffel, only recently named assistant manager, has now become manager of the physics research department at Armour Research Foundation.

Sylvania has named **Donato J. Bracco,** with the company since 1947, as manager of its chemistry laboratory.

Atomics International (NAA) has engaged **Ralph M. Wefel,** Los Angeles architect, to handle the architectural development of AI foreign nuclear powerplant proposals.

David Saxe is the new deputy manager of AEC's Chicago Operations Office succeeding **James T. Ramey,** who became executive director of the Joint Committee on Atomic Energy.

William E. Barbour, president of Tracerlab, moved up to board chairman, and **William O. Faxon** is the new president.

James K. Pickard and **Frederick H. Warren** have set up a partnership in Washington to provide management and engineering consultant services.

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May 17–19—Annual meeting, Radiation Research Society, Chicago (*Palmer House*). Contact H. S. Kaplan, Radiobiology Dept., Stanford University Hospitals, San Francisco 15.

June 6–8—American Nuclear Society, 2d annual meeting, Chicago (*Palmer House*). Contact Exec. Secy. ANS, Box 963, Oak Ridge, Tenn.

June 11–23—Symposium on High Energy Physics (European Organization for Nuclear Research [CERN]), Geneva. Novel features in design and techniques of high-energy accelerators. Contact CERN, Box 25, Geneva 15.

June 16–23—Fifth World Power Conference, Vienna. Development of power production and utilization, waste purification, international collaboration. Contact Engineers' Joint Council, 33 W 39, NYC 18.

June 21–23—Society of Nuclear Medicine, annual meeting, Salt Lake City. Contact R. G. Moffat, 2656 Heather St., Vancouver 9, B. C.

June 25–26—National Conference, Uranium & the Atomic Industry (Atomic Industrial Forum and Denver Research Institute), Denver (*Cosmopolitan Hotel.*) Contact D. J. Scherer, AIF, 260 Madison Ave., NYC 16.

June 25–27—Symposium, High Temperature: A Tool for the Future (Stanford Research Institute and University of California), Berkeley, Calif. Contact Nevin K. Hiester, SRI, Menlo Park, Calif.

June 25–29—Am. Soc. for Engineering Education, annual meeting, Ames, Iowa. Contact W. Leighton Collins, Univ. Illinois, Urbana, Ill.

July 2–7—International Nuclear Physics Congress, Amsterdam. High- and low-energy reactions. Contact Netherlands Society of Physics, Bijlhouwerstraat 6, Utrecht.

July 9–13—Conference on Radiation Chemistry (Gordon Research Conferences of the Am. Assn. for Advancement of Science), New Hampton School, New Hampton, N. H. Chemical utilization of nuclear energy; kinetics of radical reactions; radiation chemistry of aqueous systems, gases, and polymers. Two other Gordon Research meetings, both at Kimball Union Academy, Meriden, N. H., are **June 25–29** on Nuclear Chemistry and **July 2–6** on Chemistry and Physics of Isotopes. Contact W. G. Parks, University of Rhode Island, Kingston, R. I.

July 22–28—Eighth International Congress of Radiology, Mexico City. Symposia on radiodiagnosis, radiotherapy, radiation physics, X-ray technology, radiobiology. Contact José Noriega, Box 21964, México 7, D. F.

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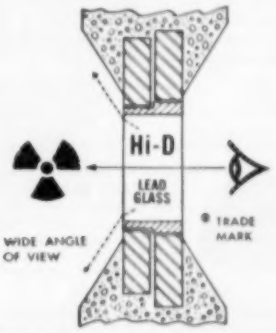

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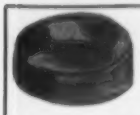

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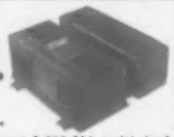

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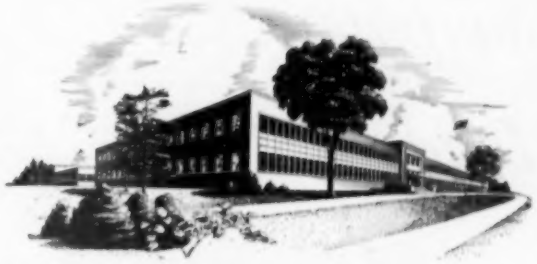

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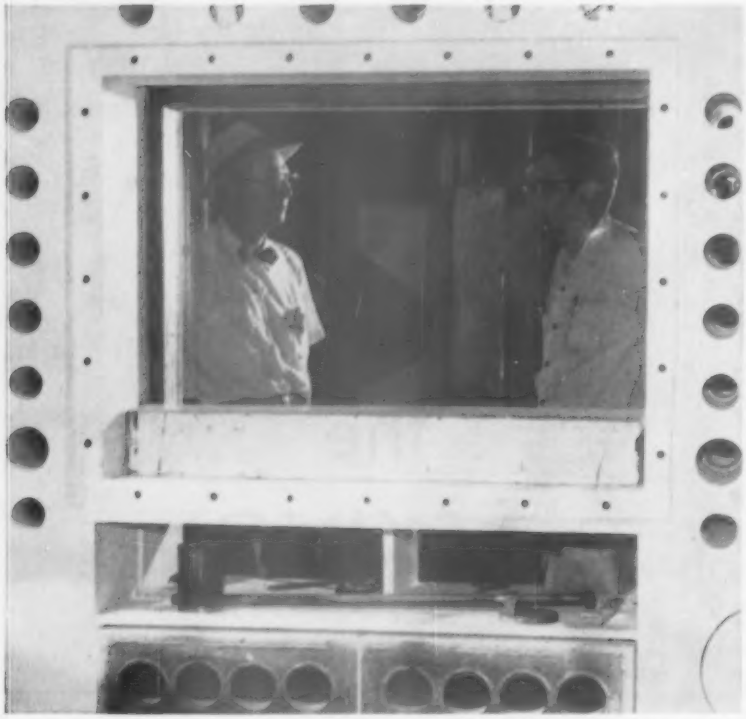

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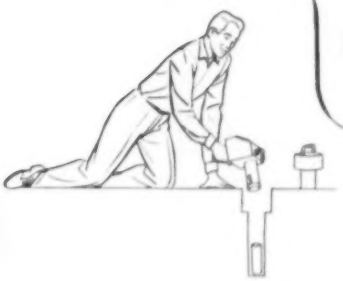

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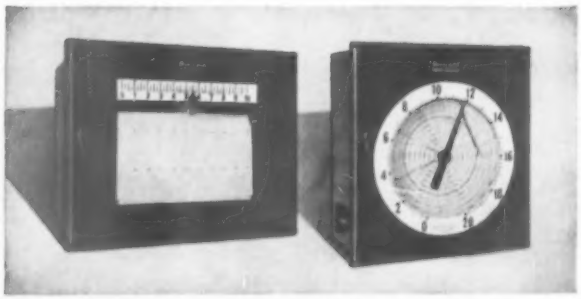

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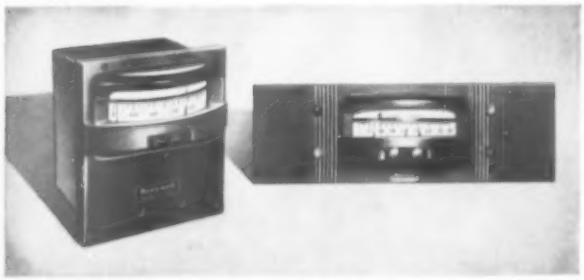

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